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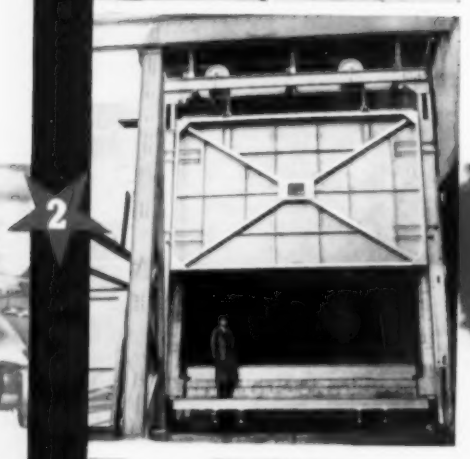

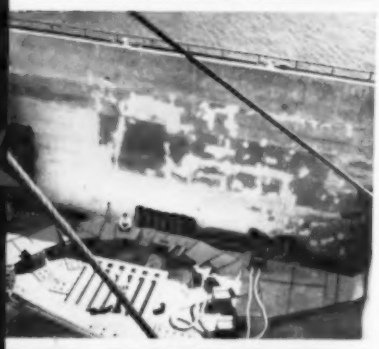

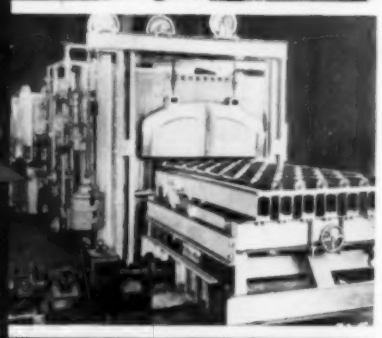

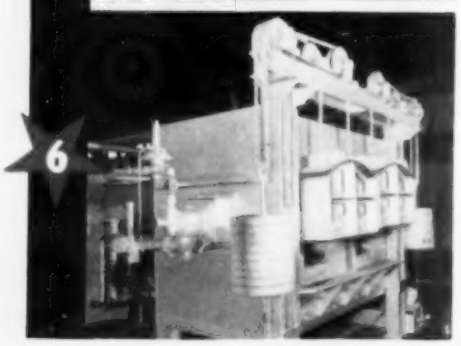

1 Car Bottom Recirculated Air Furnace for stress relieving gun carriages at Washington Navy Yard.

2 Front view of Recirculated Air Car Bottom Furnace at Washington Navy Yard.

3 Large Recirculated Air Furnace for stress relieving welded gun carriages at the Brooklyn Navy Yard. The parts treated are so large that it is necessary to remove the roof of the furnace for charging.

4 Looking down into SC Furnace. Similar SC Furnace is also installed at Philadelphia Navy Yard.

5 Completely automatic unit for hardening, quenching, and drawing shells at Frankfort Arsenal.

6 Forge Furnace at Rock Island Arsenal. Maximum temperature 2700°F.

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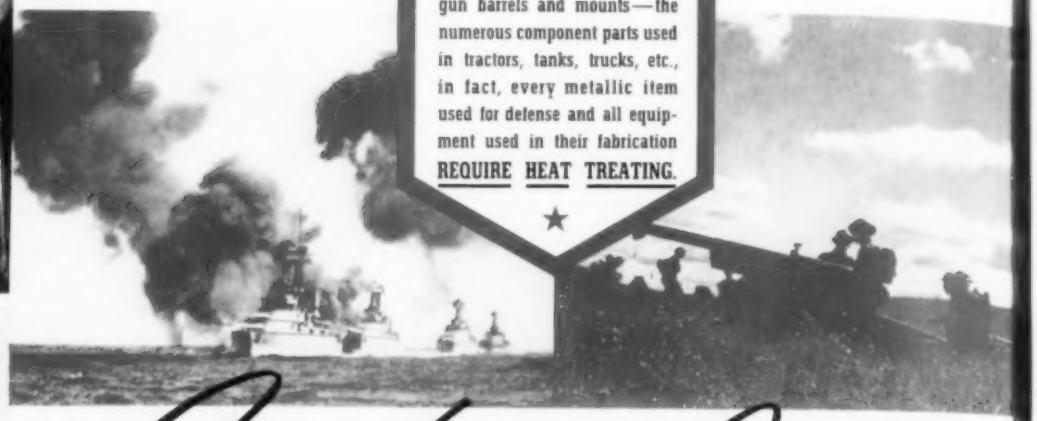
● Armor plate, aeroplane parts, shells, cartridge cases, bombs, gun barrels and mounts—the numerous component parts used in tractors, tanks, trucks, etc., in fact, every metallic item used for defense and all equipment used in their fabrication REQUIRE HEAT TREATING.



Navy Yards and Arsenals ARE SPEEDING UP FOR NATIONAL DEFENSE WITH SC FURNACES

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Metal Progress

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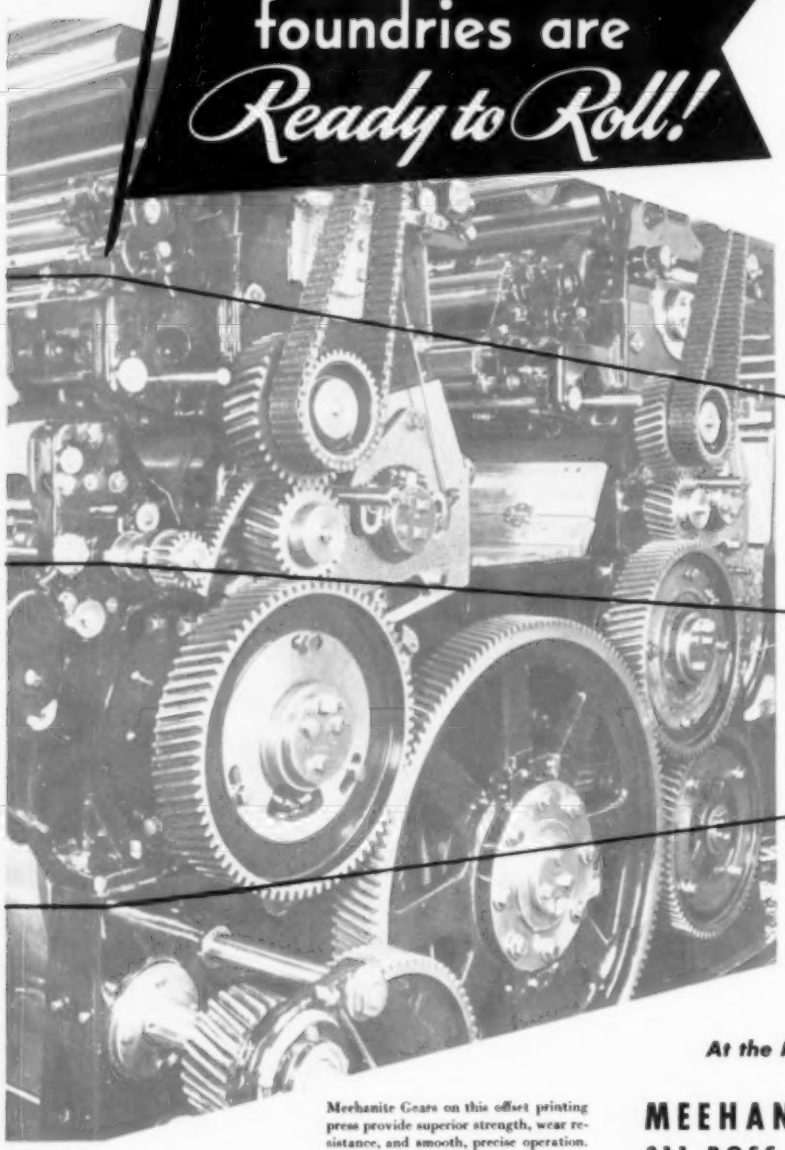

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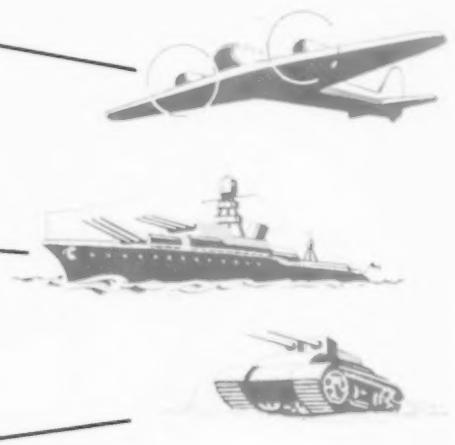

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metal progress

national metal congress & exposition

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National Metal Congress

AMERICAN SOCIETY FOR METALS — AMERICAN WELDING SOCIETY
AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS
THE WIRE ASSOCIATION — ARMY ORDNANCE ASSOCIATION

Sunday, Oct. 20, 1940

3:00 P.M. American Society for Metals ⊕ Open House; National Headquarters, 7301 Euclid Ave.
5:00 P.M. American Welding Society (A.W.S.) President's Reception; Cleveland Hotel

Monday, Oct. 21, 1940

9:30 A.M. ⊕ Technical Session; Statler Hotel
9:30 A.M. A.W.S. Presentation of Medals and Prizes; Cleveland Hotel
10:00 A.M. American Institute of Mining and Metallurgical Engineers (A.I.M.E.) (Institute of Metals and Iron and Steel Divisions) Session on Constitution of Alloys; Cleveland Hotel
10:30 A.M. Wire Association (W.A.) Directors' Meeting; Carter Hotel
10:30 A.M. A.W.S. Session on Shipbuilding and Structural; Cleveland Hotel
12:00 M. National Metal Exposition opens; Public Auditorium
12:00 M. W.A. Program Committee Luncheon; Carter Hotel
12:15 P.M. A.I.M.E. (Institute of Metals Division) Executive Committee Luncheon Meeting; Cleveland Hotel
12:15 P.M. A.I.M.E. Committee on Blast Furnace and Raw Materials Luncheon Meeting; Cleveland Hotel
12:15 P.M. A.I.M.E. Committee on Bessemer Steel Luncheon Meeting; Cleveland Hotel
1:30 P.M. ⊕ Technical Session; Public Auditorium
2:00 P.M. A.I.M.E. (Iron and Steel Division) Session on Bessemer Steel; Cleveland Hotel
2:00 P.M. A.I.M.E. (Institute of Metals Division) Session on Lead, Zinc, and Magnesium; Cleveland Hotel
2:00 P.M. A.W.S. Simultaneous Sessions on Steel Mill and Industrial Research; Cleveland Hotel
2:30 P.M. W.A. Technical Session; Carter Hotel
5:00 P.M. ⊕ Lecture Course, Strength of Metals Under Combined Stresses; Public Auditorium
6:30 P.M. A.W.S. Industrial Research Dinner and Conference; Cleveland Hotel
8:30 P.M. ⊕ Lecture Course, Quenching of Metals; Public Auditorium
10:30 P.M. National Metal Exposition closes

Tuesday, Oct. 22, 1940

8:00 A.M. ⊕ Board of Trustees Breakfast; Statler Hotel
9:30 A.M. ⊕ Simultaneous Technical Sessions; Statler Hotel
9:30 A.M. A.W.S. Simultaneous Sessions on Machinery and Fundamental Research; Cleveland Hotel
9:30 A.M. W.A. Technical Session; Carter Hotel
10:00 A.M. A.I.M.E. (Iron and Steel Division) Session on Surface Qualities; Cleveland Hotel
10:00 A.M. A.I.M.E. (Institute of Metals Division) Session on Copper and Gold; Cleveland Hotel
12:00 M. National Metal Exposition opens; Public Auditorium
12:00 M. ⊕ Canadian Luncheon; Statler Hotel
12:15 P.M. A.I.M.E. (Iron and Steel Division) Executive Committee Luncheon Meeting; Cleveland Hotel
12:30 P.M. ⊕ Past Presidents' Luncheon; Statler Hotel
1:30 P.M. ⊕ Technical Session; Public Auditorium
1:30 P.M. W.A. Technical Session; Carter Hotel
2:00 P.M. A.I.M.E. (Institute of Metals and Iron and Steel Divisions) Session on Physical Metallurgy; Cleveland Hotel
2:00 P.M. A.W.S. Simultaneous Sessions on Machinery and Fundamental Research; Cleveland Hotel
5:00 P.M. ⊕ Lecture Course, Strength of Metals Under Combined Stresses; Public Auditorium
7:30 P.M. A.W.S. Fundamental Research Conference; Cleveland Hotel
8:00 P.M. A.I.M.E. Annual Autumn Dinner; Cleveland Hotel
8:30 P.M. ⊕ Lecture Course, Quenching of Metals; Public Auditorium
10:30 P.M. National Metal Exposition closes

Wednesday, Oct. 23, 1940

7:30 A.M. ⊕ Chapter Chairmen's Breakfast; Statler Hotel
9:30 A.M. ⊕ Annual Meeting and Campbell Memorial Lecture; Statler Hotel
9:30 A.M. A.W.S. Simultaneous Sessions on Resistance Welding and Fundamental Research; Cleveland Hotel
9:30 A.M. W.A. Technical Session; Carter Hotel
12:00 M. National Metal Exposition opens; Public Auditorium
12:00 M. College Alumni Luncheons; Statler Hotel
12:15 P.M. A.I.M.E. Committee on Physical Chemistry of Steel Making Luncheon Meeting; Cleveland Hotel
1:00 P.M. W.A. Luncheon; Carter Hotel
1:30 P.M. ⊕ Simultaneous Technical Sessions; Public Auditorium
2:00 P.M. A.I.M.E. (Institute of Metals and Iron and Steel Divisions) Joint Round Table Discussion on Electrolytic Polishing of Metals; Cleveland Hotel
2:00 P.M. A.W.S. Simultaneous Sessions on Resistance Welding and Structural; Cleveland Hotel
3:00 P.M. W.A. Annual Meeting and Mordica Memorial Lecture; Carter Hotel
5:00 P.M. ⊕ Lecture Course, Strength of Metals Under Combined Stresses; Public Auditorium
7:30 P.M. W.A. Dinner and Stag Smoker; Carter Hotel
8:30 P.M. ⊕ Lecture Course, Quenching of Metals; Public Auditorium
10:30 P.M. National Metal Exposition closes

Thursday, Oct. 24, 1940

9:30 A.M. ⊕ Simultaneous Technical Sessions; Statler Hotel
9:30 A.M. A.W.S. Simultaneous Sessions on Pipe Welding, and Procedure Controls & Special Applications; Cleveland Hotel
9:45 A.M. W.A. Technical Session; Carter Hotel
12:00 M. National Metal Exposition opens; Public Auditorium
1:30 P.M. ⊕ Symposium on Surface Treatment of Metals and Simultaneous Technical Session; Statler Hotel
2:00 P.M. A.W.S. Committee Meetings; Cleveland Hotel
5:00 P.M. ⊕ Lecture Course, Strength of Metals Under Combined Stresses; Public Auditorium
6:00 P.M. National Metal Exposition closes
7:00 P.M. ⊕ Annual Banquet; Statler Hotel
7:00 P.M. A.W.S. Annual Banquet; Cleveland Hotel

Friday, Oct. 25, 1940

9:00 A.M. ⊕ Lecture Course, Strength of Metals Under Combined Stresses; Statler Hotel
9:30 A.M. ⊕ Symposium on Surface Treatment; Statler Hotel
9:30 A.M. A.W.S. Simultaneous Sessions on Metallurgical and Railroad Applications; Cleveland Hotel
11:30 A.M. A.W.S. Business Meeting; Cleveland Hotel
12:00 M. National Metal Exposition opens; Public Auditorium
1:30 P.M. ⊕ Symposium on Surface Treatment; Statler Hotel
2:00 P.M. Ordnance Conference; Public Auditorium
6:30 P.M. Army Ordnance Asso. Dinner; Cleveland Hotel
10:30 P.M. National Metal Exposition and National Metal Congress end

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ZAY JEFFRIES	1935	HARRY W. McQUAID	1938	A. W. MACHLET	1940

HENRY MARION HOWE MEDALISTS

EMANUEL J. JANITZKY	1922	EDGAR C. BAIN	1931	TRYGVE D. YENSEN	1935
FRANCIS F. LUCAS	1924	KARL HEINDLHOFER	1931	NICHOLAS A. ZIEGLER	1935
HORACE H. LESTER	1925	FRANCIS M. WALTERS	1932	A. G. H. ANDERSEN	1937
†FREDERICK C. LANGENBERG	1926	CYRIL WELLS	1932	ERIC R. JETTE	1937
WESLEY P. SYKES	1927	MAXWELL GENSAMER	1932	JOSEPH WINLOCK	1938
OSCAR E. HARDER	1928	JOHN F. ECKEL	1932	RALPH W. E. LEITER	1938
RALPH L. DOWDELL	1928	JOSEPH V. EMMONS	1933	CHARLES S. BARRETT	1939
†CARL R. WOHRMAN	1929	JOHN CHIPMAN	1934	GERHARD ANSEL	1939
HERBERT J. FRENCH	1930			ROBERT F. MEHL	1939

PUBLICATION COMMITTEE CHAIRMEN

†HERBERT M. BOYLSTON	1920–29	AUGUSTUS B. KINZEL	1932–33	WESLEY P. SYKES	1934–36
WILLIAM B. COLEMAN	1929–30	GERALD R. BROPHY	1933–34	A. ALLAN BATES	1936–38
VICTOR O. HOMERBERG	1930–32			LOUIS W. KEMPF	1938–

METALS HANDBOOK COMMITTEE CHAIRMEN

Standards Committee		*Recommended Practice Committee*		*Metals Handbook Committee*	
†TILLMAN D. LYNCH	1920–22	J. FLETCHER HARPER	1923–27	CHARLES H. HERTY, JR.	1934–36
ROBERT M. BIRD	1922–23	†WILLIAM J. MERTEN	1927–31	JAMES P. GILL	1936–37
		L. B. CASE	1931–33	RALPH L. DOWDELL	1937–39
		CHARLES H. HERTY, JR.	1933–34	ROBERT S. ARCHER	1939–

LOCATION OF CONVENTION AND EXPOSITION

1920 — PHILADELPHIA	1927 — DETROIT	1934 — NEW YORK
1921 — INDIANAPOLIS	1928 — PHILADELPHIA	1935 — CHICAGO
1922 — DETROIT	1929 — CLEVELAND	1936 — CLEVELAND
1923 — PITTSBURGH	1930 — CHICAGO	1937 — ATLANTIC CITY
1924 — BOSTON	1931 — BOSTON	1938 — DETROIT
1925 — CLEVELAND	1932 — BUFFALO	1939 — CHICAGO
1926 — CHICAGO	1933 — DETROIT	1940 — CLEVELAND

CAMPBELL MEMORIAL LECTURERS

WILLIAM M. GUERTLER	1926	CHARLES H. HERTY, JR.	1931	JAMES P. GILL	1936
ZAY JEFFRIES	1927	EDGAR C. BAIN	1932	WESLEY P. SYKES	1937
W. H. HATFIELD	1928	HERBERT J. FRENCH	1933	ALFRED L. BOEGEHOLD	1938
†ALBERT SAUVEUR	1929	VSEVOLOD N. KRIVOBOK	1934	EDMUND S. DAVENPORT	1939
MARCUS A. GROSSMANN	1930	HARRY W. McQUAID	1935	SAMUEL L. HOYT	1940

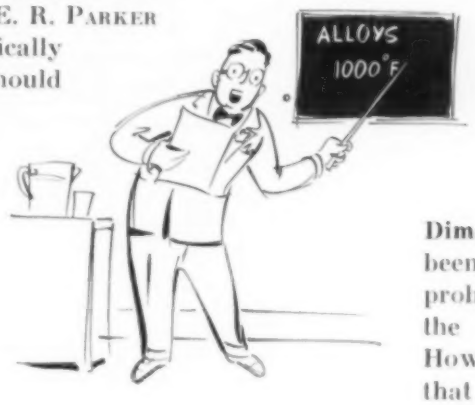
† Deceased

Technical Meetings

Monday Morning

FOR SOME TYPES of high temperature equipment **creep test** information is of prime importance; in other types long-time **rupture properties** should be given most consideration. R. H. THIELEMANN **correlates** these two tests, which should have much merit in high temperature engineering design.

A study of **high temperature properties** has indicated to General Electric's E. R. PARKER that an alloy containing a critically dispersed stable compound should possess greater high temperature strength than alloys strengthened by carbides.



An exploratory survey of the **influence of hydrogen on malleable** cast iron by Messrs. SCHWARTZ, GUILER and BARNETT represents a valuable pioneering contribution which should facilitate future work.

While much has been published concerning solid **carburizing compounds**, certain of the factors which influence the activity of such compounds have been somewhat neglected. MACK SUTTON and R. A. RAGATZ attempt to fill some of the gaps in the existing knowledge.

Monday Afternoon

OPENING a session largely devoted to furnace atmospheres, J. R. GIER of Westinghouse describes the production of a **balanced atmosphere** and a device for measuring the carburizing character of a gas, known as the "hot wire carbon gage".

Interrelation of temperature of the combustion chamber in heat treating and the **composition** of the furnace **atmosphere** is SAM TOUR's subject. An intermediate range of 1600 to 1900° F. is recommended for heat treatment.

Dimensional changes on hardening have been one of the tool maker's most baffling problems. Accurate measurements under the closest possible control made by HOWARD SCOTT and T. H. GRAY show that such changes are reproducible and can be anticipated, and the tool thus hardened to predetermined dimensions.

The problems incident to measuring and evaluating the effect of **water vapor in furnace atmospheres** are discussed in SAM TOUR's second contribution to this session, and some new light is thrown on the reactions.

National Metal Exposition Opens at 12 Noon; Closes 10:30 P. M.

Afternoon Lecture

AT 5 o'clock, MAXWELL GENSAMER of the metallurgical faculty, Carnegie Institute of Technology, will start his series of five lectures (open to ASMembers only) on **The Strength of Metals Under Combined Stresses.** Physical testing technique has evolved from efforts to test metals in simple stresses acting in one direction only, yet most metals in machines and structures act under highly complicated systems of force. The fundamental theory of such action is so recent that most metallurgists will be in a new field of knowledge when they listen to Dr. GENSAMER's interpretation.

Evening Lecture

AN essentially practical course of three lectures has been arranged by the ⊕ Educational Committee for the first three evenings of the week. Three different lecturers will teach members of the ⊕ and their invited guests. The first is A. ALLAN BATES of Westinghouse Research Laboratories. Rapid cooling **(quenching)** is the essence of the hardening operation, and many puzzling variations in results — to say nothing of damage and loss of product — may be avoided if the metallurgist understands the limitations of a metal's ability to radiate heat from center to surface, and of a quench's ability to extract heat from that surface.

Educational Course on Quenching

Technical Meetings

Tuesday Morning
Simultaneous Session

TWO objects are the aim of ERICH FETZ — to improve experimental technique of **tests on recovery** of cold-worked metals, and to study the wide range of softening of **cold-worked nickel.**

A new X-ray method for studying crystallographic orientation is based on surface diffraction, and its determination of **structural changes in hot and cold-rolled steels** is described by NORMAN P. GOSS of Cold Metal Process Co.

The familiar and useful **austenitic manganese steel** comes in for some attention from D. NICONOFF of Republic's organization, who has developed a method for measuring quantitatively its tendency toward **strain hardening.**

Equilibrium relationships in alloy systems cannot be neglected in any metallurgical technical program, so W. C. ELLIS and E. S. GREINER of Bell Telephone Laboratories tell about their detailed research into the **iron-cobalt system.**

Tuesday Afternoon

PROPER balancing of **molybdenum and columbium** with the chromium and nickel content of **stainless steels** not only enhances resistance to pit and contact corrosion but also avoids formation of the sigma phase and thus preserves toughness. A wealth of structural and corrosion data by FRANKS, BINDER and BISHOP.

Again the isothermal transformation — this time the **S-curve** of a 6% tungsten, 6% molybdenum **high speed steel.** Its practical significance is also discussed by JOHN L. HAM, ROBERT M. PARKE and ALVIN J. HERZIG of Climax Molybdenum.

The first 0.012 in. below the **surface of a high speed steel** constitutes the edge of many cutting tools. J. G. MORRISON proposes to find out more about the distribution of the carbon in this zone after heat treatment.

More about **surface carbon chemistry of high speed steel** is contributed by W. A. SCHLEGEL. He studies the effect of time, temperature and furnace atmospheres on grain size as well.

Tuesday Morning
Simultaneous Session

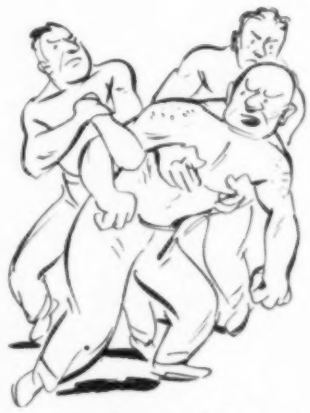
OUT of U. S. Steel Corp. Research Laboratory comes further work on the **transformation of austenite.** This time it concerns transformation **on continuous cooling** and relates the data to the isothermal diagram. R. A. GRANGE and J. M. KIEFER are the authors.

Continuing studies at the Bureau of Standards on the various factors which influence **hardenability,** THOMAS G. DIGGES now shows the **effect of grain size.** Equipment for heating in dry nitrogen and quenching in hydrogen is described, along with results on a series of high purity iron-carbon alloys.

In order to shorten and simplify investigations on austenite transformation, DONALD B. OAKLEY and JOSEPH F. OESTERLE utilize **dilatometric studies** rather than metallographic. This paper gives the results **on a molybdenum cast iron.**

While the influence of austenitic grain size on properties of steels has been widely discussed, **factors which influence grain size** have been somewhat more neglected. S. J. ROSENBERG and T. G. DIGGES consider one of these factors — namely, **rate of heating** through the transformation range.

National Metal Exposition
12 M. to 10:30 P. M.



Strength Under Combined Stress

Afternoon Lecture

CONSIDERATION of the fact that a metal may be "ductile" under one set of loads and "brittle" under another leads Dr. GENSAMER into a study of the mechanism of **failure at a sharp notch** in his second lecture on strength of metals under combined stress.

Evening Lecture

A VAST amount of information about how **quenching** is done in mass production of steel parts has been collected by Prof. W. J. CONLEY for this lecture. A few items are given in his short article on page 421 of this issue.

Technical Meetings

Wednesday Morning

Annual Meeting and Campbell Memorial Lecture

AFTER hearing President GILL, Treasurer VAN HORN, and Secretary EISENMAN tell of another record-breaking year's history of ⚙, you can listen to SAMUEL L. HOYT deliver the 1940 Edward de Mille Campbell Memorial Lecture. His subject **The Scientific Method in Metallurgy** will set a new style in these lectures, being philosophic rather than factual. He will describe the general methods used for researches in astronomy, physics, chemistry and mathematics and argue that these "scientific methods" should be more often applied to metallurgical studies, thus to insure a higher return for the expenditure of money and brains.

Wednesday Noon

Ten different engineering colleges have planned luncheon reunions for old grads.

Wednesday Afternoon

Simultaneous Session

SOME valuable discussion relative to a new and promising tool for investigation — namely, **micro-radiography** — should be excited by the first of two papers by GEORGE L. CLARK and WILLIAM M. SHAFER. (See also what TOM WRIGHT has to say about the new analytical techniques on page 551.)

CLARK and SHAFER's second contribution to this session has to do with a different application of X-rays; this is the study by diffraction of **distortion in** metals, with quantitative results reported on **silicon steel and aluminum.**

NORMAN P. GOSS's purpose in presenting a discussion of **diffraction diagrams** is principally to promote a discussion of **X-ray technique,** which he believes is of great importance in interpretation of diffraction patterns and should be standardized.

Disintegration of furnace refractories in certain gas atmospheres has been sidestepped by furnace engineers by using light weight brick instead of firebrick. JOHN H. LOUX takes a leaf from the blast furnace operator's book to prove that this is really unnecessary.

Wednesday Afternoon

Simultaneous Session

INVESTIGATIONS on **precipitation hardening** in the binary **iron-tungsten** and **iron-molybdenum** alloys are continued by W. P. SYKES of G.E.'s Cleveland Wire Works. This paper is concerned with hardness changes, behavior of single-phase and two-phase alloys, and effect of cooling rate.

A significant addition to the scant information existing on the commercially important **powdered copper alloys** is the data on compacting pressure and temperature provided by CLAUS C. GOETZEL.

The **precipitation reaction** in phosphor bronzes is evaluated in terms of practical application of commercial material, as well as in terms of a revised **copper-tin** equilibrium diagram. R. H. HARRINGTON and R. G. THOMPSON of General Electric's research laboratories give the details.

One atom of silver in 5000 atoms of copper can produce a remarkable change in properties, particularly in raising the recrystallization temperature. E. R. PARKER of the same organization attributes this to precipitation in the grain boundaries and generalizes on the high temperature effect of **impurities in copper.**

Afternoon Lecture

CERTAIN simplified assumptions are now to be more exactly defined by Dr. GENSAMER in his third lecture on Strength of Metals Under Combined Stresses. Principal modifying factors to be considered are **temperature, amount** of deformation **and speed of deformation.**

Evening Lecture

THE final meeting of the evening lecture series will consider **quenching** practices as observed **in custom** heat treating **shops,** and the lecturer will be ROY G. ROSHONG of Lindberg Steel Treating Co. (a firm from which many good ideas and devices have come).

National Metal Exposition Opens at 12 Noon; Closes 10:30 P. M.

Technical Program

Thursday Morning
Simultaneous Session

VALUABLE information of a quantitative nature on the extent to which **nitrogen** plays a part in **case carburizing** is given by S. W. POOLE of Republic Steel.

Further light on the more complex alloy systems is furnished by C. L. CLARK and M. A. BREDIG's study of the constitutional diagram of **4 to 6% Cr-Mo steels** containing silicon and aluminum.

Climax Molybdenum researchers have been intensively studying the **effect of molybdenum on S-curves** of various steels. Their second paper on this subject has to do with low and medium carbon steels containing 0.15 to 0.75% "moly". Authors are JAMES BLANCHARD, ROBERT PARKE and ALVIN HERZIG.

Difference in behavior of "similar" steels is often attributed to small differences in alloy content. AUSTIN and NORRIS pin down the effect of **small amounts of alloy** by adding various elements to pure iron-carbon alloys.

Thursday Afternoon
Simultaneous with Symposium
(see next page)

HOW the **fatigue and bend** tests can be used to study the effect of cold working on the physical properties of wire is shown by H. J. GODFREY, who also includes some metallographic and X-ray data on the structure of **cold-drawn steel wire.**

Three types of "stress raisers" affect fatigue strength — namely, notches, corrosion, and chafing or fretting. G. SACHS and P. STEFAN of Case School consider **chafing fatigue strength** and its relation to the other two types.

Aircraft materials are a timely subject for BRICK and PHILLIPS' study of **fatigue and damping** properties. Specifically they report on duralumin, alclad and several types of 18-8 in sheet form.

In a fourth paper on **alloys of manganese and copper,** R. S. DEAN reports on their unusually high vibration **damping** capacity, and relates it to composition and treatment. Co-authors are C. T. ANDERSON and E. V. POTTER.

Thursday Morning
Simultaneous Session

PURSUING studies suggested by a former paper indicating that presence of alumina in steel may serve as a graphitizer, AUSTIN and FETZER (Pennsylvania State College) report the relation between **carbide stability,** grain size, **abnormality,** and hardenability.

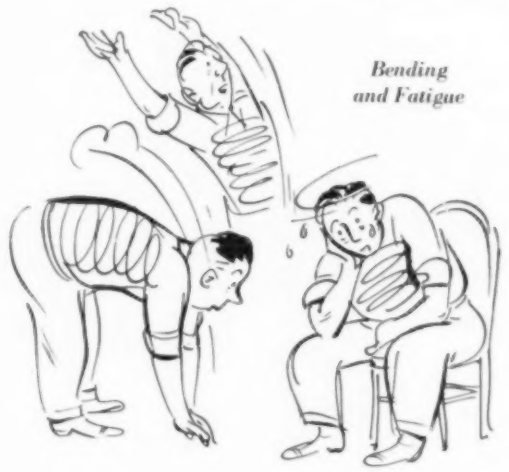
Hardenability is a linear function of grain size at heat treating temperature, and **independent** of the method **of deoxidation,** say G. V. CASH, T. W. MERRILL and R. L. STEPHENSON (Carnegie-Illinois Steel Corp.)

Hardenability is considered again by Carnegie-Illinois authors — this time M. A. GROSSMANN and R. L. STEPHENSON. They find that the greater the **hardenability** the more it is affected by **change in grain size.**

One method of estimating **hardenability** and quenching effects utilizes round bars. The same principles are applied and the method extended to plates and **irregular shapes,** as described by ASIMOW and GROSSMANN.

Afternoon Lecture

HAVING spent three lectures in discussing the conditions that determine whether or not a metal will plastically deform, it is now necessary for Dr. GENSAMER to consider the conditions that determine **when it will break.**



Bending and Fatigue

Annual Banquet of the American Society for Metals

Assemble at the Grand Ballroom, Hotel Statler, for a good meal and a rousing talk, right off his chest, by "Old Iron Pants" — Gen. HUGH JOHNSON.

Technical Program

Friday Morning Early

9 O'CLOCK! Prof. MAXWELL GENSAMER resurrects the old college scourge, an early morning lecture, in which he will describe various **tests and processes** that illustrate the general principles laid down in his preceding four talks on the strength of metals under combined stresses.

Symposium on Surface Treatment of Metals

Thursday Afternoon
Simultaneous Session

OPENING the symposium JUNIUS D. EDWARDS describes the **anodic treatment of aluminum,** which has developed from a method or procedure to a highly technical art of great commercial value.

Stainless steel is the next metal whose surface treatment is considered. Allegheny Ludlum's G. C. KIEFER discusses the various **passivation** treatments **and coloring** processes.

The most important **surface treatments for magnesium alloys** are those which provide protection against corrosion, and "tooth" for paint. SCHMIDT, GROSS and DELONG of Dow Chemical Co. evaluate the chemical treatments according to these criteria.

And the lowly tin can is not neglected. American Can Co.'s R. R. HARTWELL uses acid fruits to determine the preferred steel base composition for optimum **corrosion resistance of the tinplate.**

Zinc coatings produced by hot dipping and electrogalvanizing are analyzed from the point of view of unit operations, equipment, cost, and properties by J. L. BRAY and F. R. MORRAL.

Surface Finish and Structure

Induction heat treating will take its place among the indispensable tools of the industry claims EDMUND BLASKO, who describes unconventional work done at Ford Motor Co. that should broaden the applications considerably.

Explanations of the **characteristics of induction hardening** such as speed of carbide solution, thorough diffusion, and high hardness, are described by M. A. TRAN and H. B. OSBORN, Jr. of "Tocco" fame.

Damage to the surface of **structural steel** between the time it leaves the mill and until fabrication is completed often affects the adherence of the paint coat. **Flame cleaning** and dehydrating, as described by J. G. MAGRATH, is claimed to eliminate this difficulty.

Friday Afternoon

A NEW method of surface finishing known as **shot blasting,** which was first protested, then tolerated, then finally specified and boosted, is described by F. P. ZIMMERLI. He cites 40% increase in fatigue life of valve spring wire.

O. J. HORGER and H. R. NEIFERT are also concerned with **fatigue** in their studies at Timken. They compare **effects of surface conditions** had by machining with the fatigue properties of burnished, metal sprayed, and flame hardened surfaces.

Friday Morning

CONTINUING the Symposium, FREDERICK N. RHINES of Carnegie Tech discusses the fundamentals of **diffusion coating.** These include such varying cementation processes as calorizing, carburizing, chromizing, siliconizing, and sherardizing.

A paper on **surface reactions and diffusion** is concerned with the theoretical aspects of such hardening processes as carburizing, nitriding and cyaniding. Messrs. DORN, GIER, BOELTER and WARD of California University analyze them quantitatively.

Future advances in machining efficiency lie in the direction of reducing coefficient of **friction** between chip and tool, say HANS ERNST and EUGENE MERCHANT.

Rated as the beginning of important work on the bright annealing of **stainless steel** are VERNON HOLM's observations at the National Bureau of Standards.

The correlation of the **profile tracer** method with microscopic observation of surface irregularities is shown by ERNEST J. ABBOTT of Physicists Research Co.

Last Day, National Metal Exposition; 12 Noon to 10:30 P. M.

American Welding Society

Technical Program

Sunday, October 20

5:00 to 7:00 P.M. — President's Reception
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Monday, October 21

9:30 A.M. — Presentation of Medals and Prizes
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

10:30 A.M.—Shipbuilding and Structural Session
HOTEL CLEVELAND

Welding in Shipbuilding
by *David Arnott*, American Bureau of Shipping
Welded Rigid Frame Structures
by *A. Amirikian*, Navy Department

2:00 P.M. — Steel Mill Applications
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Resistance Flash Welding of Strip in Steel Mills
by *J. H. Cooper*, Taylor Winfield Corp.
Design and Fabrication of Heavy Rolling Mill Machinery
by *G. W. Linkhauer*, United Engineering & Foundry Co.
Shape Cutting in Steel Mill
by *Joseph Stanley*, Carnegie-Illinois Steel Corp.
Hard Facing Steel Equipment
by *Frank L. Gray*, Carnegie-Illinois Steel Corp.

2:00 P.M. — Industrial Research
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Testing for Weldability of Carbon Steels
by *C.E. Jackson* and *G.G. Luther*, Naval Research Laboratory Anacostia Station
Defects in Weld Metal and Hydrogen in Steel
by *Carl A. Zapffe* and *C. E. Sims*, Battelle Memorial Institute
Improving Ductility of Oxy-Acetylene Welds by Aging
by *J. R. Dawson* and *A. R. Lytle*, Union Carbide & Carbon Research Laboratories
Metallurgical Changes at Welded Joints, and the Weldability of Steels
by *R. H. Aborn*, U. S. Steel Corp. Research Laboratories

6:30 P.M. — Industrial Research Committee Dinner and Conference
HOTEL CLEVELAND

Informal After-Dinner Remarks
William O. Hotchkiss, Pres., Rensselaer Polytechnic Institute

Tuesday, October 22

9:30 A.M. — Machinery
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Operation Problems in the Small Welding Shop
by *Roger B. White* and *J. T. Lewis, Jr.*, Lewis Welding & Eng. Corp.
Welding Electrical Machinery
by *R. A. Taylor*, Westinghouse Electric & Mfg. Co.
Flame Machining — Control and Applications
by *G. L. Walker* and *W. G. Sylvester*, Air Reduction Sales Co.

9:30 A.M. — Fundamental Research
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

A Method of Studying the Effects of Inertia and Friction in Resistance Welding Machines
by *W. F. Hess* and *R. A. Wyant*, Rensselaer Polytechnic Institute
The Welding of Carbon-Molybdenum Piping for High Temperature High Pressure Service
by *R. W. Emerson*, Pittsburgh Piping & Equipment Co.
Micro-Fissuring in Multiple Bead, Low Carbon Steel Welds
by *J. L. Miller* and *L. R. Kovac*, Armour Institute of Technology

2:00 P.M. — Machinery
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Flame Hardening
by *R. H. Zeilman*, Thew Shovel Co.
Production Flame Hardening of Machine Parts
by *John Erler* and *P. H. Tomlinson*, Farrel-Birmingham Co., Inc.
High-Speed Mechanized Oxy-Acetylene Welding
by *H. T. Herbst*, The Linde Air Products Co.
Machine Flame Cutting in Preparation for Welding
by *W. Roy Widdoes*, By-Products Steel Corp.
Use of Welding and Cutting in the Fabrication of Ditching Equipment
by *A. R. Askue*, Cleveland Trencher Co.

2:00 P.M. — Fundamental Research
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Welded Girders With Inclined Stiffeners
by *Cyril Jensen* and *C. Antoni*, Lehigh University

Measurement of Contact Resistance
by *W. B. Kouwenhoven* and *Joseph Tampico*, Johns Hopkins University
Electrodes for Welding Cast Iron
by *Gilbert S. Schaller*, University of Washington
Fundamentals of Resistance Welding
by *R. S. Pelton*, General Electric Co.

7:30 P.M. — Fundamental Research Conference
HOTEL CLEVELAND

American Welding Society

Technical Program
(Continued)

Wednesday, October 23

9:30 A.M. — Resistance Welding
ROSE ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Resistance Welding Electrodes — Some Fundamental Considerations
by *G. N. Sieger*, S-M-S Corp.

Changes in the Shape of Spherical Spot-Welding Electrodes
by *W. F. Hess* and *R. A. Wyant*, Rensselaer Polytechnic Institute

Recorders and Indicators for Resistance Welding Machines
by *W. C. Hutchins*, General Electric Co.

9:30 A.M. — Fundamental Research
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

The Effect of the Physical State of Steel Upon the Tensile Strength of Brazed Joints
by *F. C. Kelley*, General Electric Co.

Crater Formation and the Force of the Electric Welding Arc in Various Atmospheres
by *G. E. Doan*, Lehigh University and *R. E. Lorentz*, Combustion Eng. Co.

Cold Rolling Testing of Welds
by *T. P. Hughes* and *R. L. Dowdell*, University of Minnesota

2:00 P.M. — Resistance Welding
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Scope and Limitations of the Stored Energy Type Resistance Welding
by *C. Weygandt*, University of Pennsylvania and *G. S. Mikhalapov*, Baldwin-Southwark

A Study of Spot Welding on a Copper Base Alloy
by *M. L. Wood* and *J. Babin* and *O. B. Atkin*, Chase Brass & Copper Co.

Stored Energy Systems of Spot Welding
by *H. B. Axtell* and *R. L. Ringer, Jr.*, Taylor-Winfield Corp.

Electro-Brazing Methods
by *R. J. Wensley*, I-T-E Circuit Breaker Co.

Spot Welding in Aircraft Construction
by *C. F. Marschner*, McDonnell Aircraft Corp.

2:00 P.M. — Structural Welding
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Shall We Weld Our Bridges?
by *Fred L. Plummer*, Hammond Iron Works

Flexible Welded Angle Connections
by *Bruce Johnston* and *L. F. Green*, Lehigh University

Design and Construction of Arc Welded Steel Structures
by *La Motte Grover*, Air Reduction Sales Co.

Flame Cleaning of Structural Steel
by *F. H. Dill*, American Bridge Co.

Investigation of Gas in Piping

Thursday, October 24

9:30 A.M. — Pipe Welding
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Pipe Welding for the Naval Service
by *Bela Ronay*, U. S. Naval Engineering Experiment Station

Welding of Copper and Red Brass
by *J. J. Freeland* and *J. Babin*, Chase Brass & Copper Co.

Investigation of Gas and Arc Fillet Welds in Piping
by *I. H. Carlson* and *Eric R. Seabloom*, Crane Co.

Preheating — Welding — Normalizing
by *C. J. Holslag*, Electric Arc Cutting & Welding Co.

9:30 A.M. — Procedure Controls and Special Applications
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Cost and Procedure Control by Use of Polarized Light
by *E. W. P. Smith*, Lincoln Electric Co.

Training of Welding Operators
by *S. Lewis Land*, Supervisor of Industrial Education, N. Y. State Dept. of Education

Codes for Welded Pressure Vessels
by *D. S. Jacobus*, Babcock & Wilcox Co.

Oxy-Acetylene Welding of Light Aircraft
by *Hanford Eckman*, Piper Aircraft Corp.

Design and Construction of Large Welded Cement Kilns
by *C. A. Malmberg*, Allis-Chalmers Mfg. Co.

2:00 P.M. — Committee Meetings
HOTEL CLEVELAND

7:00 P.M. — Annual Banquet
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Friday, October 25

9:30 A.M. — Metallurgical Session
BALL ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Dilution of Austenitic Welds by Mild Steel and Low Alloys
by *R. David Thomas, Jr.* and *K. W. Ostrom*, Arcos Corp.

Silver and Alloy Soldering
by *C. Zappone*, Robertshaw Thermostat Co.

9:30 A.M. — Railroad Applications
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Welding in Tank Car Construction
by *J. W. Sheffer*, American Car & Foundry Co.

Welding of Passenger Cars
by *A. M. Unger*, Pullman-Standard Car Mfg. Co.

11:30 A.M. — Business Meeting, American Welding Society
RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

Annual Report of the President
Election and Installation of New Officers
Presentation of Past-President's Pin

12:15 P.M. — Luncheon

Board of Directors, American Welding Society
HOTEL CLEVELAND

Friday Afternoon — Inspection Trip

Iron and Steel Division — Institute of Metals Division

American Institute of Mining and Metallurgical Engineers

Technical Program

Monday, October 21

9:00 A.M. — Registration

CONFERENCE SUITE LOUNGE, PARLOR FLOOR, HOTEL CLEVELAND

10:00 A.M. — Constitution of Alloys

EMPIRE ROOM, PARLOR FLOOR, HOTEL CLEVELAND

An Investigation on the Structure and Properties of Some Iron-Nickel Alloys
by *George Sachs* and *J. Spretnak*, Case School of Applied Science

Precision X-Ray Study of the High Silver Aluminum-Silver Alloys
by *Frank Foote*, Cooper Union and *Eric R. Jette*, School of Mines, Columbia University

X-Ray Analysis of Hot-Galvanized Heat Treated Coatings
by *F. R. Morral*, Continental Steel Corp. and *E. P. Miller*, Purdue University

12:15 P.M. — Luncheon Meetings

Executive Committee, Institute of Metals Division

PRIVATE DINING ROOM NO. 1, MEZZANINE FLOOR, HOTEL CLEVELAND

Committee on Blast Furnaces and Raw Materials

PRIVATE DINING ROOM NO. 5, MEZZANINE FLOOR, HOTEL CLEVELAND

Committee on Bessemer Steel

PRIVATE DINING ROOM NO. 9, MEZZANINE FLOOR, HOTEL CLEVELAND

2:00 P.M. — Bessemer Steel

(*Iron & Steel Division*)

EMPIRE ROOM, PARLOR FLOOR, HOTEL CLEVELAND

The Acid Bessemer Process of 1940
by *H. W. Graham*, Jones and Laughlin Steel Corp.

The Method of Dephosphorization of Bessemer Steel
by *Gordon M. Yocom*, Wheeling Steel Corp.

2:00 P.M. — Lead, Zinc, Magnesium

(*Institute of Metals Division*)

ROOMS 34 AND 36, PARLOR FLOOR, HOTEL CLEVELAND

Creep and Recrystallization of Lead
by *Albert A. Smith, Jr.*, American Smelting and Refining Co.

Tensile Properties of Rolled Magnesium Alloys: Binary Alloys With Calcium, Cerium, Gallium, and Thorium
by *John C. McDonald*, Dow Chemical Co.

X-Ray Study of the Solid Solutions of Lead, Bismuth, and Gold in Magnesium
by *Frank Foote*, Cooper Union and *Eric R. Jette*, School of Mines, Columbia University

The Grain Orientation of Cast Polycrystalline Zinc, Cadmium and Magnesium
by *Gerald Edmunds*, The New Jersey Zinc Co.

Tuesday, October 22

10:00 A.M. — Surface Qualities

(*Iron & Steel Division*)

EMPIRE ROOM, PARLOR FLOOR, HOTEL CLEVELAND

Surface Finish and Structure
by *John Wulff*, Massachusetts Institute of Technology

Analysis of the Cold-Rolling Texture of Iron
by *Charles S. Barrett* and *L. H. Levenson*, Carnegie Institute of Technology

10:00 A.M. — Copper and Gold

(*Institute of Metals Division*)

ROOMS 34 AND 36, PARLOR FLOOR, HOTEL CLEVELAND

Coalesced Copper; Its History, Production and Characteristics
by *H. H. Stout*, Consulting Metallurgical Engineer

The Hydrogen Embrittlement of Pure Copper
by *Frederick N. Rhines* and *William A. Anderson*, Carnegie Institute of Technology

The Effect of Composition Upon Physical and Chemical Properties of 14-K Gold Alloys
by *Tracy C. Jarrett*, American Optical Co.

12:15 P.M. — Luncheon

Executive Committee, Iron & Steel Division

PRIVATE DINING ROOM NO. 1, MEZZANINE FLOOR

2:00 P.M. — Physical Metallurgy

EMPIRE ROOM, PARLOR FLOOR, HOTEL CLEVELAND

A Study of the Metallography and Certain Physical Properties of Some Alloys of Cobalt, Iron and Titanium
by *Charles R. Austin* and *Carl H. Samans*, Pennsylvania State College

Measurement of Irreversible Potentials as a Metallurgical Research Tool
by *R. H. Brown*, *William L. Fink* and *M. S. Hunter*, Aluminum Co. of America

On the Solidification of Solid Solutions Under Equilibrium Conditions
by *Morris Cohen*, Massachusetts Institute of Technology and *William P. Kimball*, Dartmouth College

8:00 P.M. — Annual Autumn Dinner

RED ROOM, MEZZANINE FLOOR, HOTEL CLEVELAND

After-Dinner Speaker: *Rolland C. Allen*, Past-President A.I.M.M.E.; "Strategic Minerals and Metals"

Wednesday, October 23

12:15 P.M. — Luncheon

Committee on Physical Chemistry of Steel Making

PRIVATE DINING ROOM NO. 1, MEZZANINE FLOOR

2:00 P.M. — Round Table Discussion

EMPIRE ROOM, PARLOR FLOOR, HOTEL CLEVELAND

Electrolytic Polishing of Metals — Metallographic and Commercial
Leaders: *Sam Tour*, Lucius Pitkin, Inc. and *Hugh E. Brown*, W. S. Tyler Co.

The Wire Association

[A registration fee of $5.00 is required. Admission will be by badge only.]

Monday, October 21

10:30 A.M. — Directors' Meeting
HOTEL CARTER

12:00 M. — Luncheon, Program Committee
HOTEL CARTER

2:30 P.M. — First Technical Session
HOTEL CARTER

Tungsten Carbide Dies and Tools
by *James R. Longwell*, Carboloy Co.
Recent Developments in Heating Copper Wire Bars
by *Joseph A. Doyle*, W. S. Rockwell Co.
Electric Direct Resistance Wire Treating
by *J. P. Zur*, Trauwood Engineering Co.

Tuesday, October 22

9:30 A.M. — Second Technical Session
HOTEL CARTER

Lime for the Wire Industry
by *D. E. Washburn*, American Lime & Stone Div., The Warner Co.
Electro Chemical Applications in the Wire Industry
by *C. L. Mantell*, Consulting Engineer, New York City
Motion Picture: Application of Tungsten Carbide Tools and Dies
by Firth-Sterling Steel Co.

1:30 P.M. — Third Technical Session
HOTEL CARTER

The Endurance Properties of Hard Drawn Wire From Various Kinds of Copper
by *John N. Kenyon*, Columbia University
Reactive Wire Drawing
by *H. A. Stringfellow*, Worcester, Mass.
Motion Picture: Copper From Mine to Market
by *H. A. Stout*, Phelps Dodge Copper Products Co.

Wednesday, October 23

9:30 A.M. — Fourth Technical Session
HOTEL CARTER

What Does Good Laboratory Practice Do to Help Production in the Steel Plant?
by *George P. Lenz, Jr.*, Union Drawn Steel Division, Republic Steel Corp.
Galvanizing Characteristics of Different Types of Steels
by *Robert W. Sandelin*, Atlantic Steel Co.

1:00 P.M. — Wire Association Luncheon
HOTEL CARTER

After-Luncheon Speaker: *C. M. White*, Republic Steel Corp:
"Steel Quality and Labor Relationship"

3:00 P.M. — Annual Meeting and Mordica Memorial Lecture
HOTEL CARTER

The Use of Plane Polarized Light and Sensitive Tint Illumination in the Analysis of the Microstructure of Steel
by *B. L. McCarthy*, Wickwire Spencer Steel Co.

7:30 P.M. — Annual Dinner and Stag Smoker
HOTEL CARTER

Thursday, October 24

9:45 A.M. — Fifth Technical Session
HOTEL CARTER

Design and Operation of a New Copper Wire Drawing Plant
by *H. Blount*, Point Breeze Works and *J. E. Wiltrakis*, Kearny Works, Western Electric Co.
Development of Apparatus for Shaving Copper Wire Commercially
by *C. E. Weaver*, General Electric Co.

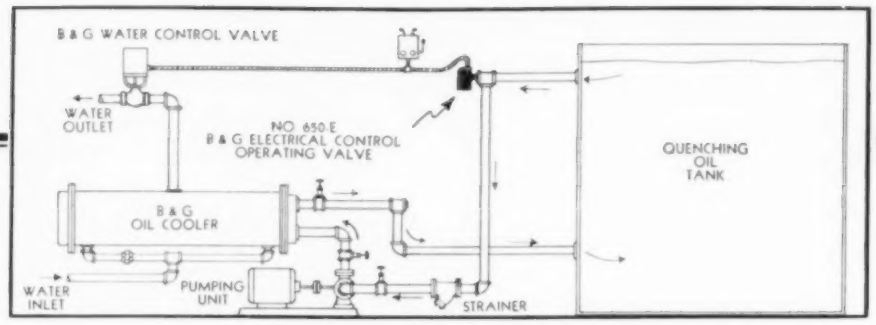
Army Ordnance Association

(Cleveland Ordnance District)

Friday, October 25

2:00 P.M. — Recent Developments in Ordnance Materials
PUBLIC AUDITORIUM
Discussion led by Brig. Gen. G. M. Barnes

7:00 P.M. — Dinner
BALL ROOM, CLEVELAND HOTEL
After-Dinner Speaker:
Maj. Gen. C. M. Wesson, Chief of Ordnance, U. S. Army:
"The Ordnance Department's Role in National Defense"



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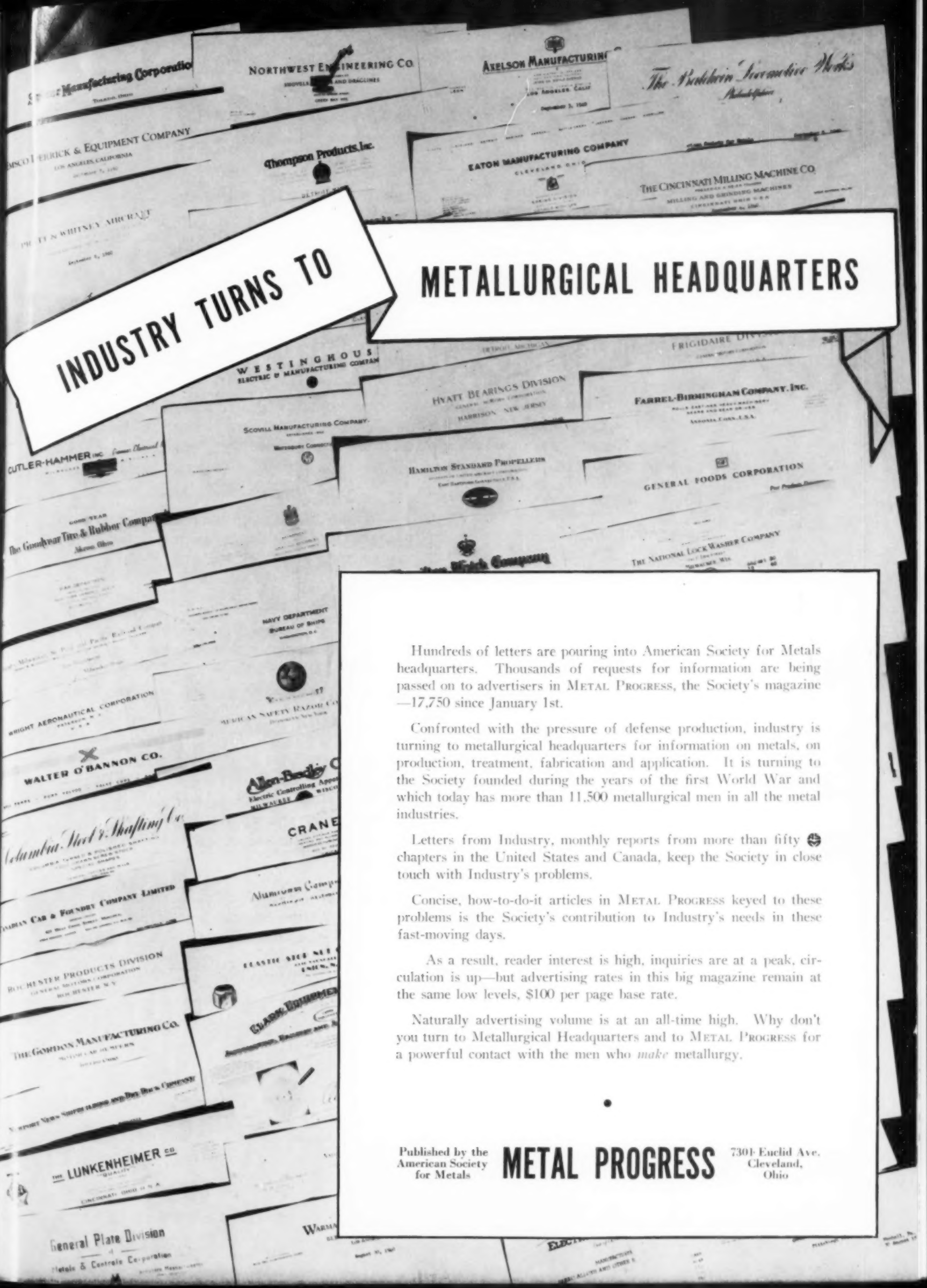

Hundreds of letters are pouring into American Society for Metals headquarters. Thousands of requests for information are being passed on to advertisers in METAL PROGRESS, the Society's magazine —17,750 since January 1st.

Confronted with the pressure of defense production, industry is turning to metallurgical headquarters for information on metals, on production, treatment, fabrication and application. It is turning to the Society founded during the years of the first World War and which today has more than 11,500 metallurgical men in all the metal industries.

Letters from Industry, monthly reports from more than fifty chapters in the United States and Canada, keep the Society in close touch with Industry's problems.

Concise, how-to-do-it articles in METAL PROGRESS keyed to these problems is the Society's contribution to Industry's needs in these fast-moving days.

As a result, reader interest is high, inquiries are at a peak, circulation is up—but advertising rates in this big magazine remain at the same low levels, $100 per page base rate.

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Metals are the Backbone

IS METALLURGICAL HEADQUARTERS

During the first World War—in 1915—industry became acutely conscious of its need for reliable technical information that would solve production problems. An active group of metal men founded an organization that is today the American Society for Metals—over 11,000 strong and growing—metallurgical headquarters for the world.

Today—twenty-five years after the birth of the ASM—industry is again confronted with the pressure of war-time production. But today metal men are equipped to meet their problems, thanks to ASM's work through Metal Progress . . . Chapter activities . . . and the National Metal Exposition.

Since 1930 ASM men have been reading Metal Progress each month to keep abreast of technical developments in their field. Metal Progress was conceived by them—to meet their specific editorial requirements. Before the first issue went to press a complete survey was made of all members—and their interests and needs dictated the editorial policy of this unusual publication from the first.

The Editorial Theme

Thus from the beginning the editorial theme has been based on facts and more facts. There has been no guesswork as to what should or should not go into Metal Progress. The magazine was designed to tell the technical story of metals—their production, treatment, fabrication and application—to tell this story simply, clearly and briefly, in language that would appeal to the technical and non-technical man alike.

In this effort, the Editor has had the helpful and critical cooperation of fifty ASM chapters in every important industrial section in the United States and Canada. He has had the ASM membership—the largest and finest group of technically-trained metal men in the world—to draw upon for original editorial material. All articles are written exclusively for Metal Progress. There are no puffs, no editorial fillers or editorial advertisements.

METAL P

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...e of the Defense Program

TALK TO THE MEN WHO KNOW METALS

These men have no casual interest in metals. They are paying Ten Dollars or more a year to be a member of the American Society for Metals and read METAL PROGRESS, cash proof of their deep interest in metals, their production, treatment, fabrication and application.

These men represent the largest single group of metallurgical men available today through any publication—11,881 net paid as of Sept. 1st.

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Engineers (Chief Engineers, Plant Engineers, Design Engineers, Metallurgical Engineers, Welding Engineers)	1,743
Metallurgists (Chief Metallurgists, Plant or Works Metallurgists, not research or laboratory)	1,823
Technical Men (Technical Directors, Research Directors, Chief Chemists, etc.)	1,161
Shopmen	591
Sales	1,389
Army & Navy	159
Educational	1,249
Purchasing, Consulting & Misc. Company Per.	168
Miscellaneous	76
Total—as of Sept. 1—	11,881

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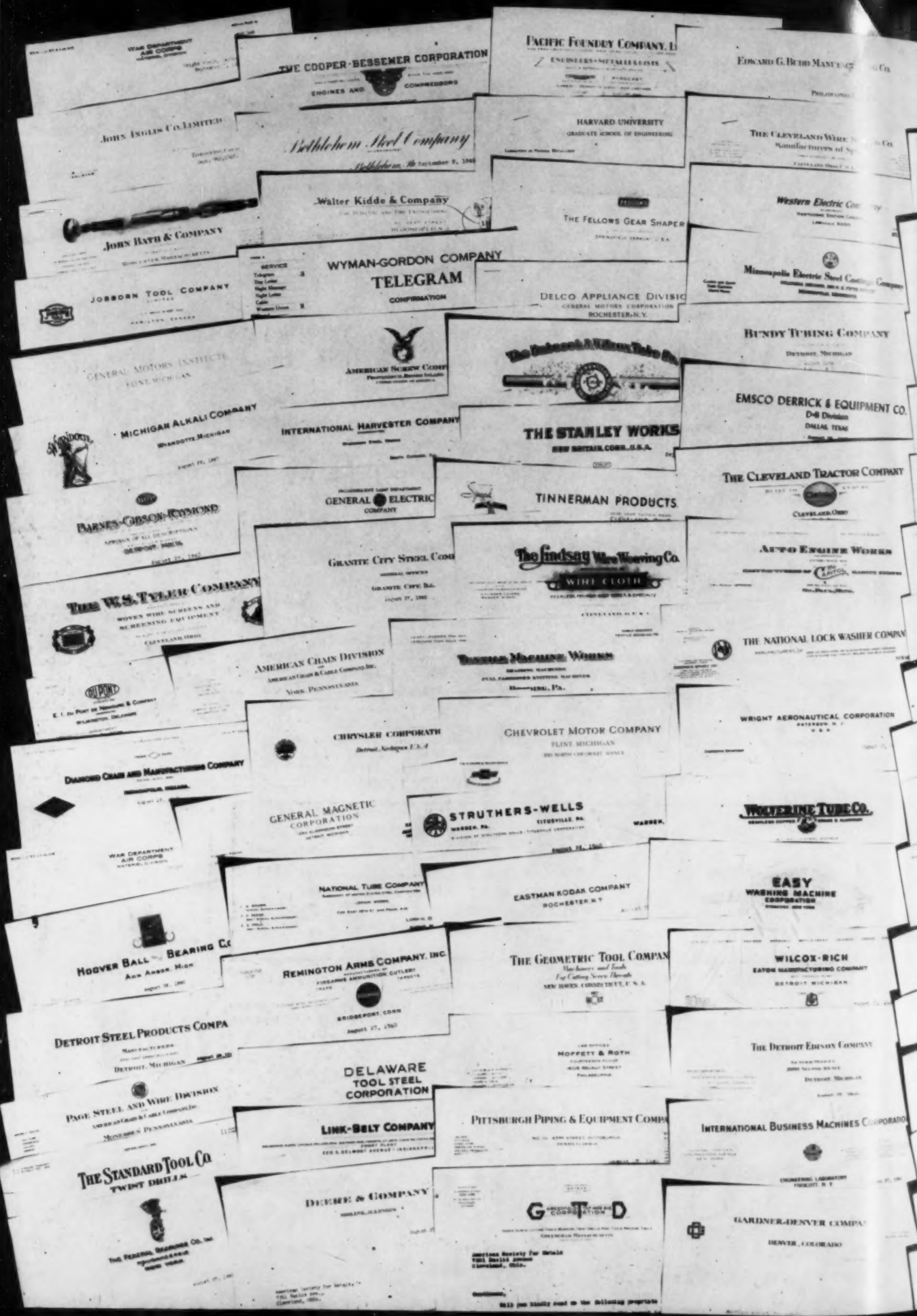
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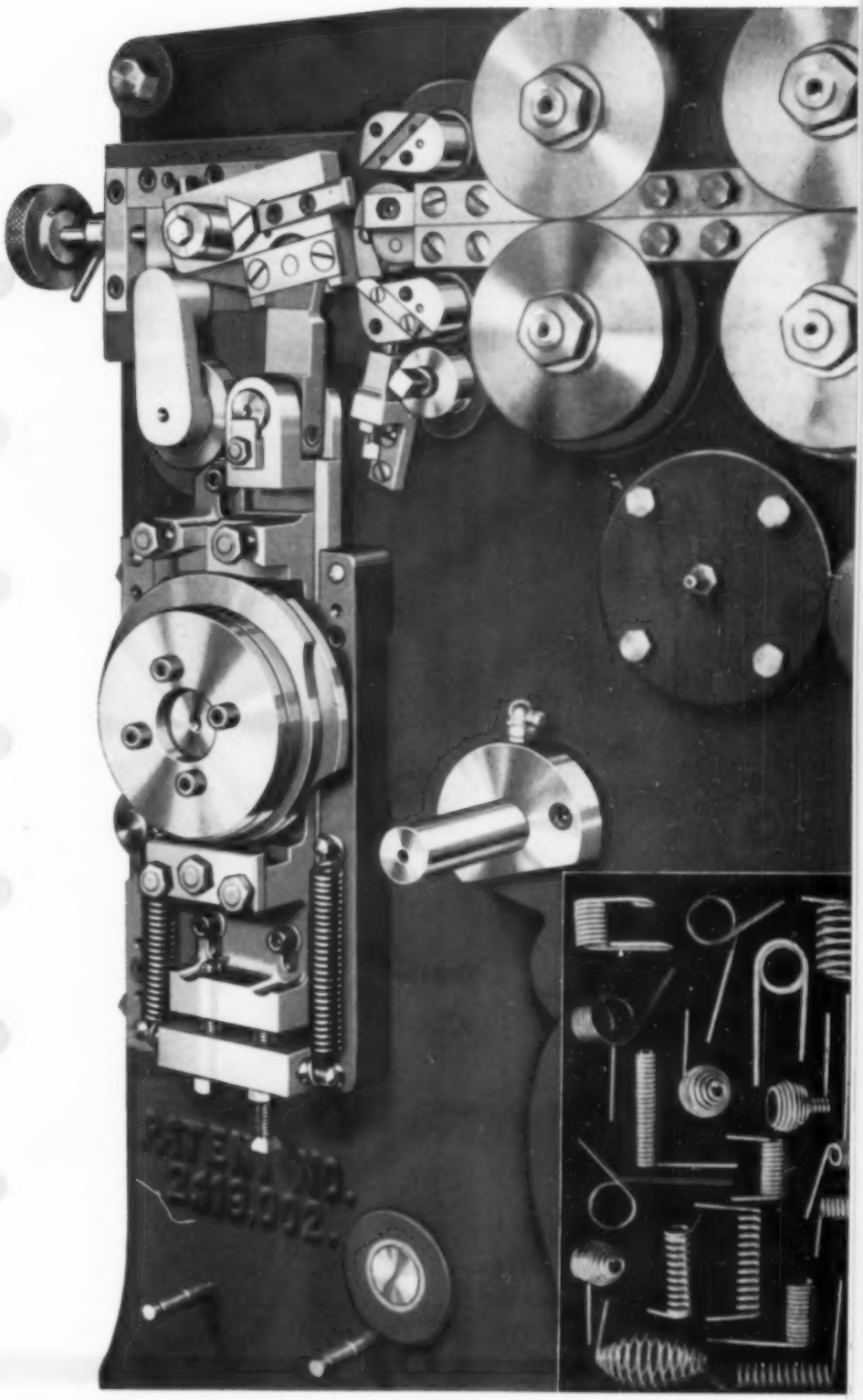

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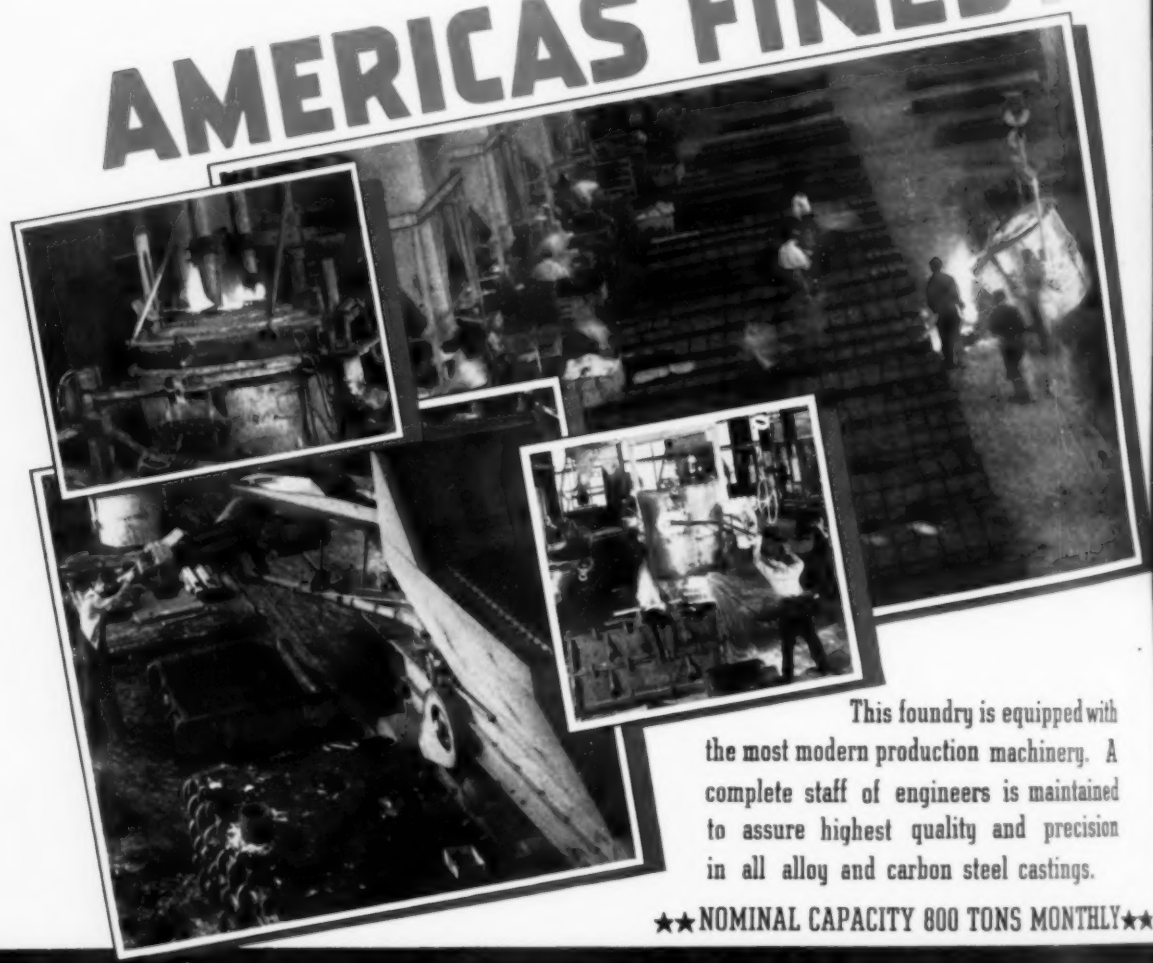

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This Industry Is Prepared

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These are some of the factors which have prevented more rapid progress in the national defense program. They are conditions that must be met — and surmounted.

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We have the plants — almost unlimited capacity to produce on short notice.

We have trained men, familiar with the technique of producing steel castings in infinite variety.

We have the experience, gained in producing for industry, castings that extend over the entire range of machines and parts for machines — everything that can be cast in steel.

We have the engineering skill and personnel that can be called upon to design and test — and to experiment with new ideas where necessary.

The Steel Castings Industry is proud of its long years of faithful service to American manufacturers — proud of its record for quality and promptness and reliability.

And we are grateful for the opportunity to serve America in its present emergency. Even though today's need for preparedness was not foreseen by our most thoughtful statesmen, our industry **is** prepared — now.

Personals

M. H. Pakkala is now metallurgist on silicon steel at the Vandergrift plant of Irvin Works, Carnegie-Illinois Steel Corp., Vandergrift, Pa.

Carl A. Arend, Jr., Ch.E. University of Cincinnati, is in the anodizing department of Hoosier Lamp & Stamping Corp., Evansville, Ind.

William Rodgers has been made chief metallurgist of Republic Steel Corp., Cleveland District.

L. P. Tarasov, formerly research metallurgist for General Electric Co., Cleveland, is now metallurgist for Beryllium Corp., Reading, Pa.

Edward Pringle has resigned as assistant chief engineer of Columbus McKinnon Chain Co. to take charge of engineering for the J. G. Wilson Corp., Norfolk, Va.

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Erle F. Ross, engineering editor of *Steel*, has been made Chicago editor of Penton publications, including *Steel*, *Daily Metal Trade* and *The Foundry*.

John E. Walker, formerly with Babcock and Wilcox Tube Co., is now on the metallurgical force of Pittsburgh Steel Co., Monessen, Pa.

N. H. Ceaglske, formerly assistant professor of metallurgy at the State University of Iowa, is now assistant professor of chemical engineering at Washington University.

R. A. Wilde has received a Master's degree from University of Illinois and is now a process development engineer in the engineering development plant of The Linde Air Products Co., Newark, N. J.

Milo J. Stutzman, formerly professor of metallurgy, Kansas State College, Manhattan, Kan., is now metallurgist in the new laboratory of Yates-American Machine Co., Beloit, Wis.

F. H. Andrews, formerly district manager of the New York office, tank car section, has been made manager of the tank car section, Philgas Division, Phillips Petroleum Co., Detroit.

Lt. N. A. Matthews has resigned as assistant chief metallographer at the Lorain, Ohio plant of National Tube Co. for extended active duty in the laboratory division of Watertown Arsenal, Watertown, Mass.

R. O. Griffis, research engineer, has returned to the research department of Bethlehem Steel Co., Bethlehem, Pa., after three years with Richard Thomas & Co., South Wales, England.

C. D. D'Amico has completed work for a Ph.D. in metallurgical engineering at the University of Michigan, and is now metallurgist in the materials department, Standard Oil Co. of California, Berkeley, Calif.

W. H. Simmons has a position as practice apprentice in the metallurgical division of Carnegie-Illinois Steel Corp.

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Only alloy steels have high resistance to corrosion, oxidation, scaling, and creep. Such steels are essential throughout industry wherever equipment is exposed to severe corrosion, excessive heat, or both . . . Wherever severe service demands a tough, abrasion-resistant steel, as in dipper buckets, dredging pumps, and rock crushers, alloy steels are the answer.

High-Strength Structural Steels

High-tensile, mild-alloy steels combine high strength with good ductility in the as-rolled state. Used as structural steels, they reduce dead weight and increase pay load.

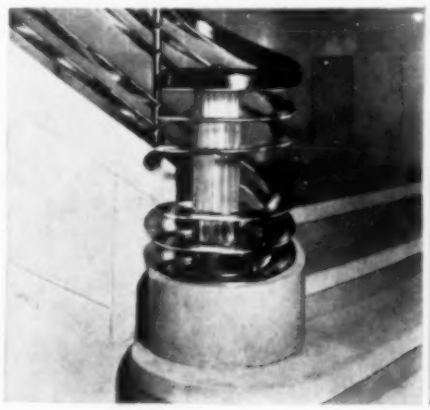
Let Us Help You

We do not make steel, but have for over 30 years produced "Electromet" ferro-alloys and alloying metals used in making steel. During this time, we have co-operated with the steel industry in developing new and better alloy steels for the specialized needs of industry. If you have any questions regarding the manufacture, fabrication, or use of alloy steels for a specific purpose, we shall be glad to help you find the answers, without obligation to you.

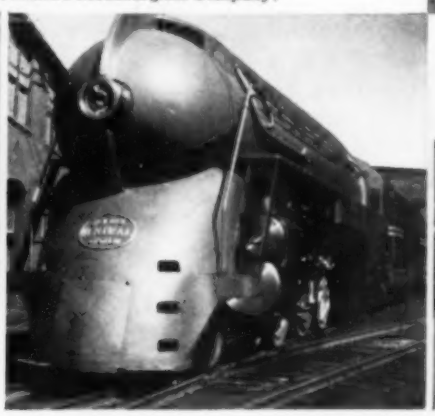
ELECTRO METALLURGICAL COMPANY
Unit of Union Carbide and Carbon Corporation
UCC
30 East 42nd Street, New York, N. Y.
In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

The word "Electromet" is a registered trade-mark of Electro Metallurgical Company.

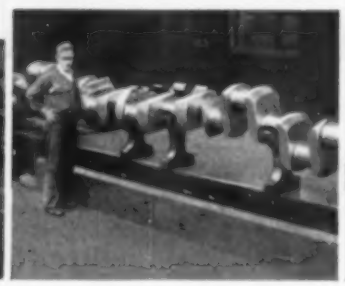
Strength and Ductility—*High-strength structural steels containing small amounts of chromium, manganese, and silicon transfer many pounds from dead load to pay load in such things as bridges and railroad cars.*



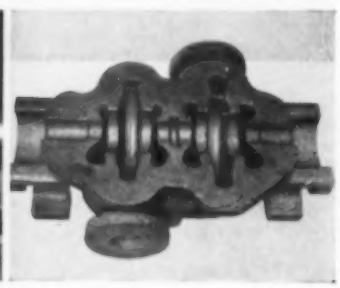
Rustlessness—*Steel made stainless and weatherproof with chromium is an architectural material of lasting luster and beauty, and wide utility.*



Fatigue Resistance—*The elasticity and high endurance ratio that vanadium imparts to steel help prevent fatigue failure under dynamic loads.*



Hardness and Strength—*Chromium, manganese, and tungsten raise hardenability, strength, toughness.*



Tough, Ductile Castings—*Vanadium and zirconium give impact strength and ductility to steel castings.*

Visit Us at the Metal Show

What properties are imparted to steel by various alloying elements will be shown at our exhibit in Area D-14, National Metal Show, Public Auditorium, Cleveland, Ohio, October 21-25. Don't miss it!

Electromet
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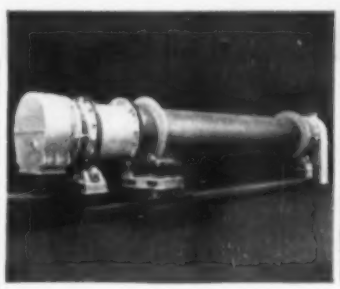

Corrosion and Heat Resistance—*Chromium and columbium give these properties to process equipment.*

Impact Strength and Wear Resistance—*Mining equipment is made tough with manganese and chromium.*

P-8960

Personals

Appointments by Carnegie-Illinois Steel Corp.: **Maurice B. Sunderland** ⊜, transferred to the Pittsburgh office as metallurgical engineer handling sheet and strip. **Charles F. Dickinson** succeeds Mr. Sunderland as manager of the sheet and strip bureau, metallurgical division, Chicago. **Paul R. Lawrence** ⊜ succeeds Mr. Dickinson as assistant to the general superintendent of the Gary sheet and tin mills. **John N. Crombie** succeeds Mr. Lawrence as manager of the tin plate bureau, metallurgical division, Chicago. **Earl H. Davidson** ⊜ to Pittsburgh as metallurgical engineer, handling structural and plate. **Charles H. Jackman** succeeds Mr. Davidson as manager of the structural and plate bureau, metallurgical division, Chicago. **Elmer Gammeter** ⊜, contact representative, becomes manager of the stainless steel bureau, metallurgical division, Chicago.

James C. Hodge ⊜, formerly chief metallurgist for Babcock & Wilcox Co., Barberton, Ohio, is now vice-president and director, Wellman Engineering Co., Cleveland, manufacturers of heavy machinery and special steel mill equipment.

Appointed manager of sales, Hill-Chase and Co., Philadelphia: **Thomas J. Moore** ⊜, formerly district manager for the Columbia Steel and Shafting Co., and manager of Edgar T. Ward's Sons Co.

Frank W. Robertson ⊜, formerly sales manager of the Ungerer Leveler division for Edward W. Voss, Pittsburgh manufacturer of rolling mill machinery, has been made general manager of both the Ungerer Leveler and the machine tool division. **Clyde DeVilling,** formerly with Universal Cyclops Steel Corp., has been placed in charge of heavy machinery sales.

H. E. Ardahl ⊜, formerly chief metallurgist of John Deere Tractor Co., Waterloo, Iowa, has been appointed assistant to the vice-president of Michiana Products Corp., Michigan City, Ind. **LaRue P. Bensing** ⊜ has been appointed as representative for Michiana in the Cleveland territory.

W. H. Steinkamp ⊜ has been transferred from Buffalo to Cleveland, as industrial manager of the Brown Instrument Division of the Minneapolis-Honeywell Regulator Co.

Promoted: **Carl H. Samans** ⊜ from assistant professor to associate professor of metallurgy in the School of Mineral Industries of the Pennsylvania State College, State College, Pa.

Carl T. Eyring ⊜ has completed work for his B.M.E. at Cornell and has joined Bethlehem Steel Co. as a member of the "loop course".

Thorwald Christensen ⊜, University of Illinois, is now with Columbia Tool Steel Co., Chicago Heights, Ill.

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Your part in the National Preparedness Program requires "stepped-up" efficiency both on your regular production and on government orders.

Avoid a "bottle-neck" in your cleaning, finishing and inspection departments by consulting Detrex engineers for approved methods. Follow government specifications in the cleaning of aircraft and automotive engines and parts, propellers, robots, radio equipment, photographic and optical instruments, indicating and control devices, shells and arms, special mechanisms, sheet metal parts, etc.

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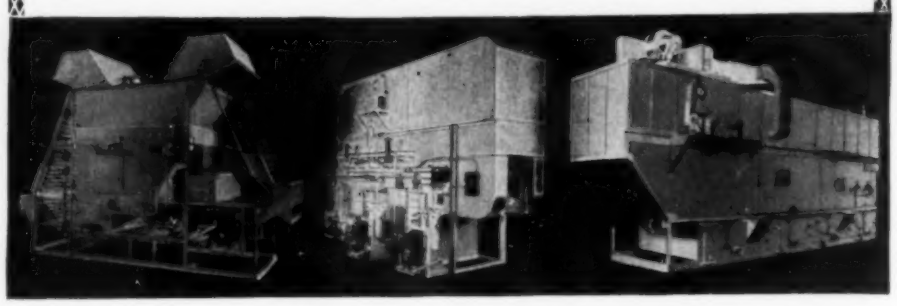
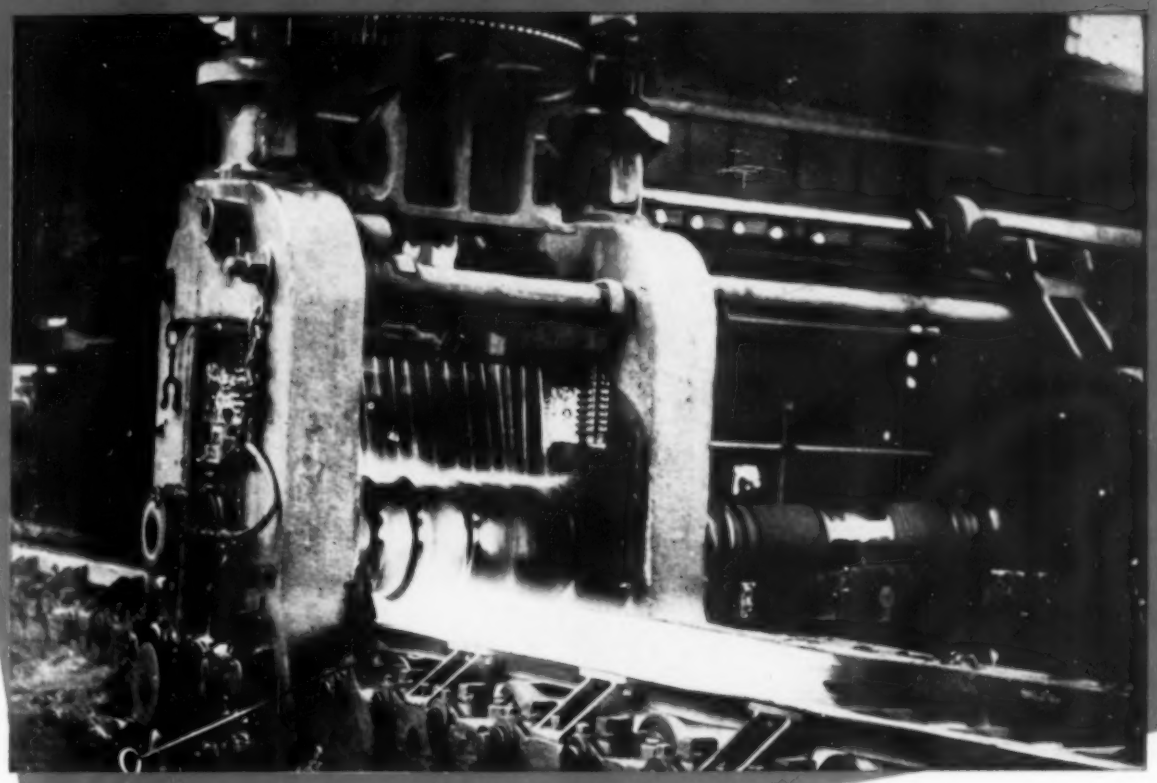


ALLOY STEELS *on the MOVE!*



You'll find some of the reasons at BOOTH Y-2

AS STEEL production soars today, the uses and demands for alloy steels are greater than ever before.

That's because an ever greater number of today's jobs require the increased strength and greater endurance that only an alloy steel can give.

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Personals

G. W. Higgins is now in the openhearth department, Inland Steel Co., Indiana Harbor, Ind.

Paul Peltier, Jr. is metallurgical observer with the Campbell plant of the Youngstown Sheet & Tube Co., Brooklyn, N. Y.

Robert F. Koenig is in the metallurgical laboratory of the Cleveland Graphite Bronze Co., Cleveland.

Van Fisher is teaching three courses in the "Photography Workshop" of New York University, one of which is on "Photo-Journalism" or the pictorial reporting he has successfully done for METAL PROGRESS for the last four years. (P.S. — METAL PROGRESS received an "Award of Merit" in *Industrial Marketing's* competition at the last meeting of the National Industrial Advertisers Association for his story in the May issue on "Crucible Steel Made in America".)

W. Richison Schofield, formerly chief engineer of Leeds & Northrup Co., Philadelphia, has been appointed director of engineering. **John W. Harsch**, assistant chief engineer, has been advanced to chief engineer, and Mr. Harsch's former position has been filled by the promotion of **John F. Quereau**.

Warren N. Hall is now with Allegheny Ludlum Steel Co. as assistant to superintendent of the electric melting department.

C. L. Clark, formerly research engineer, University of Michigan, is now research metallurgical engineer, Steel and Tube Division, Timken Roller Bearing Co., Canton, Ohio.

J. M. Bates is now employed as assistant metallurgist for the Carbide and Carbon Chemicals Corp., Charleston, W. Va.

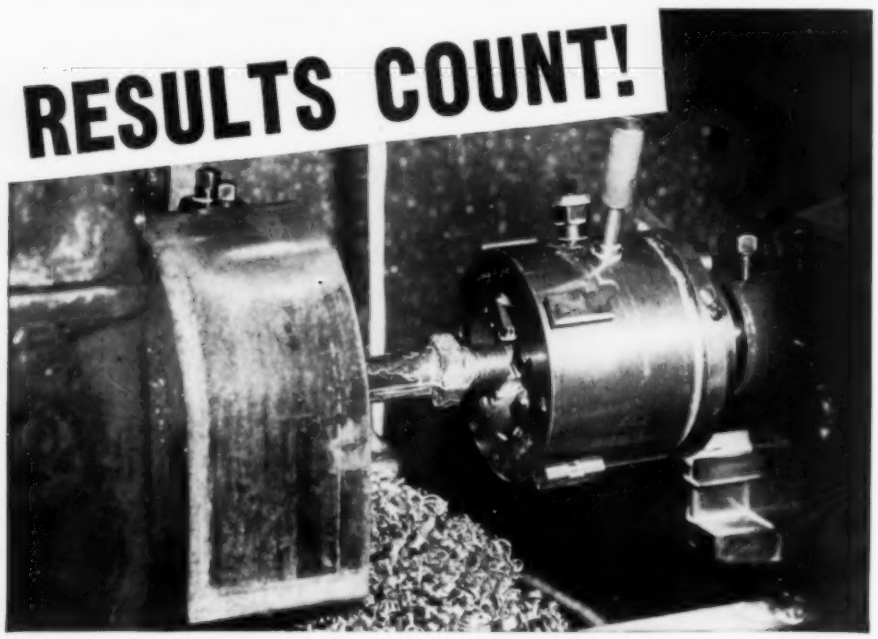
Kenneth S. Cowlin is employed by the Electro Refractories & Alloys Corp., Buffalo.

J. G. McCallum, past chairman, Golden Gate Chapter, has closed his metallurgical laboratory in Oakland, Calif., to take the position of superintendent of the new Pacific Carbide & Alloys Co. plant in Portland, Ore.

Bertrand S. Norris, formerly instructor at Pennsylvania State College, is now a metallurgical engineer in the research laboratory of U. S. Pipe and Foundry Co. in Burlington, N. J.

Appointed by the National Academy of Sciences as a committee to review suggested new processes for the recovery of manganese from low grade domestic ores: **James H. Critchett** of Union Carbide & Carbon Corp.; **Charles H. Herty, Jr.** of Bethlehem Steel Co.; **John Johnston** of U.S. Steel Corp. Research Laboratories; and **Gilbert Seil** of E. J. Lavino & Co.

A. T. Greiner, formerly in charge of Salem Engineering Co.'s work in France, and **Thomas Breene**, associated with Salem Engineering Co., Ltd., London, have returned to the U.S. and are now in the sales department of the company at Salem, Ohio.



"Excellent results for over five years have proved the value of Cities Service Cutting Oils in all of our operations, including threading, tapping and drilling," writes the purchasing director of a large electrical manufacturing company.*

This is but one of many examples where Cities Service Metal Cutting Lubricants have justified the title, "Service Proved." We will welcome an opportunity to tell you more about them and about our Lubrication Engineers' Service. Just fill out the coupon below and mail it for further information.

Copies of our booklet, "Metal Cutting Lubrication" are still available to users of metal cutting lubricants. Write for your copy today before the supply is exhausted.

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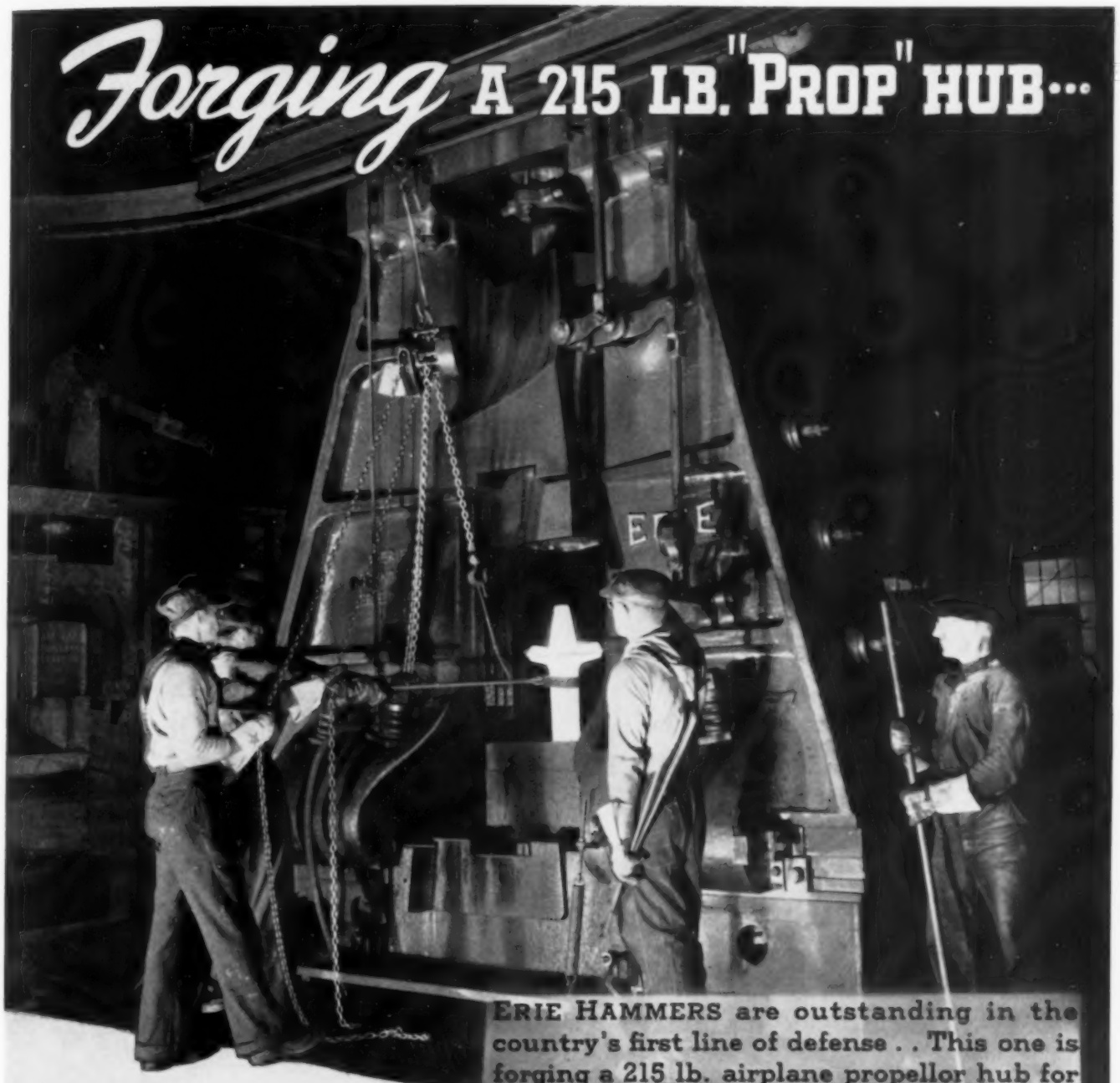

ERIE HAMMERS are outstanding in the country's first line of defense . . This one is forging a 215 lb. airplane propellor hub for a radial motor . . . The material is nitriding steel . . . 40 years of experience in design and construction of hammers for the forging industry qualify ERIES for the speedy forging of parts for the machines of preparedness or peace.

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Look at that chip!

It's low carbon *Speed Case* (X1515) . . . an open hearth steel plate that machines far more readily than other carbon steels without tearing and readily takes a satin smooth finish.

Speed Case can be cut at speeds of 250 to 300 surface f.p.m. with 5 to 15 times longer tool life because of low tool temperatures. Its physical properties are higher than ordinary steels with high shear, impact and torsional resistance and ductility that permits 180° cold bends without fracture.

Carburizing time is reduced as much as 20%; a uniform deep case results; fibrous core is tough. No warpage or "run-outs" occur in machining or heat-treating. Magnetic coefficiency is low.

Use *Speed Case* for rubber, plastic and glass molds, roller dies, stripper plates, cut gears and sprockets, fabricated power shovel dippers, motor and generator housings and other parts demanding the advantages offered by *Speed Case*.

Speed Treat (X1545), a medium carbon open hearth steel, offers similar cost cutting values plus excellent heat-treating properties.

They are the steels for today — let us tell you more about them—stop in at Booth Z122, National Metal Show, Cleveland, October. 21 to 25

SPEED CASE FREE MACHINING OPEN HEARTH STEEL PLATE

Quality Controlled *Speed Case* and *Speed Treat* Steels are available in all common plate sizes, hot rolled and cold finished bars and billets.

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Beale McCarthy & Rogers, Buffalo, N. Y. — Horace T. Potts Co., Philadelphia, Pa. — Brown-Wales Company, Boston, Mass. — The Burger Iron Company, Akron, Ohio — Peckover's, Ltd., Toronto 2, Canada

Heat Treatment

Park-Kase

A leaflet by Park Chemical Co. contains complete information concerning a new liquid carburizer of rapid and uniform penetration. Unique features and advantages of the bath are backed up with technical data. Bulletin Na-141.

Anti-Scaling Compound

An oxide armor for steel parts exposed to high heat which triples the life of the steel is described in an interesting illustrated booklet released by E. F. Houghton & Co. Bulletin Gd-38.

Case Hardening

The Pioneer two-component carburizing bath-Aerocase manufactured by the American Cyanamid & Chemical Corp. is described in detail in a two-color folder just released. Bulletin Kd-148.

Chapmanizing

Chapmanizing, the method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Flame Hardening

"Flame Hardening Apparatus", a new 12-page bulletin issued by the Air Reduction Co., makes available details and apparatus involved in flame hardening surfaces of various forms. Bulletin Kd-69.

Tocco Process

The marvel of all heat treaters—the Tocco Process of Induction Hardening—is fully described in a colorful folder by the Ohio Crankshaft Co. Bulletin Lc-145.

Electric Salt Bath Furnaces

Users' reports on work treated in the Ajax-Hultgren salt bath furnace are described and operating data for cyaniding, carburizing, hardening high speed steel, etc., are given in literature of Ajax Electric Co., Inc. Bulletin Cd-43.

Induction Heating Equipment

High frequency induction heating equipment for rapid, accurately controlled localized heating, melting, brazing is covered by folders released through Ecco High Frequency Corp. Bulletin Kd-281.

Rapid Oil Cooler

New leaflet by Bell and Gossett shows the importance of keeping the oil quenching bath at a constant temperature in the heat treatment of metals, and describes the new B & G Oil-Cooler. Bulletin Kd-287.

Carburizing Salt

A technical service bulletin describing a new development—DuPont Carburizing Salt—for the economical production of deep high-carbon cases on plain carbon and alloy carburizing steels . . . available through DuPont. Bulletin Dc-29.

Furnaces Industrial Ovens Refractories

Furnace Experience

Facts developed through 32 years of engineering and building practically every type of industrial fuel equipment can be obtained through Flinn & Dreffein Co. Bulletin Bc-82.

Hardening Furnace

A pamphlet which describes "Certain Curtain" furnaces made by C. I. Hayes, Inc., will be particularly interesting to those with hardening problems. Bulletin Nc-15.

Metal Heating

Improvements in furnace economies, operating conditions and appearance, furnaces that will more satisfactorily meet old requirements or handle new processes, service that will help solve the most stubborn problems are offered and described by Mahr Mfg. Co. in Bulletin Ea-5.

Model "Y"

The Sentry Model "Y" electric furnace, using the Sentry Diamond Block method of heat treatment, provides exceptional quality high speed steel hardening at minimum production cost. The furnace is described in Bulletin Oy-114.

New Electric Furnace

An electric furnace that is new in every respect . . . including new insulating refractory lining, increased wall insulation, simplified door lift mechanism . . . is described in a bulletin released by the American Electric Furnace Co. Bulletin Gd-2.

Clean Hardening

Continuous clean hardening machines for work ranging from extremely small, light springs, stamping, drop forgings, etc., up to quite large and heavy pieces are described in a bulletin by the American Gas Furnace Co. Bulletin Ed-11.

Oil Burners

North American Mfg. Co. offers a bulletin describing improved low pressure oil burners, one type especially designed for automatic control and ideally suited for use with proportioning control valves. Bulletin Na-138.

Industrial Furnaces

The Rockwell Furnace line, developed over half a century, is described in an attractive folder released by W. S. Rockwell Co. Bulletin Kc-34.

Motor Blower

Blowers used for oil and gas burning are featured in an interesting booklet by Ingersoll-Rand. Bulletin Kd-222.

Bright Annealing

Various types of electric and fuel-fired furnaces built by the Electric Furnace Co. for bright-annealing wire, tubing, strip and other products are described in an 8-page folder. Bulletin Lb-30.

Industrial Furnaces

Furnaces of all types are fully described in technical bulletins made available by the Eclipse Fuel Engineering Co. Bulletin Hc-226.

Heat Treating

A folder by Industrial Heating Equipment Co. explains and illustrates diagrammatically a continuous type heat treating furnace in which temperature can be held to within extremely close limits, and in which the product is always uniformly heated. Bulletin Ga-168.

Electric Furnaces

A new catalog on electric furnaces and pyrometers has been released by the Hoskins Manufacturing Company. For anyone who does any kind of heat-treating, brazing or uses heat-resisting castings. Bulletin Hc-24.

Vap-O-Gas

Vapofier Corporation equipment offers the only complete, instantly usable stand-by safeguard available for use with fuel oil or gas through the same burners and manifolding. If you have heat treating equipment in your plant investigate the advantages of economy and efficiency of Vapofier. Bulletin Kd-290.

Firebrick

Technical data on B&W insulating firebrick can be obtained through the Babcock & Wilcox Co. Bulletin Fc-75.

Portable Electric Furnace

A unique portable electric furnace designed for use at temperatures below 1100° F. with drawing salts and oil tempering baths is described in a booklet by Claud S. Gordon Co. Bulletin Ed-53.

Controlled Combustion

Direct Fired Air Heaters which make possible Controlled Combustion and permit wider range in oven and furnace operation are explained in a 4-page folder by the Despatch Oven Co. Bulletin Lc-123.

Insulation

A 32-page catalog containing specific information on all of the sheet, block and pipe insulations developed by the Johns-Manville Company is now available through that company. Bulletin Fb-100.

New Furnace Principle

An amazing new principle of furnace combustion that offers the fastest, most economical heat available today has been developed by Radiant Combustion, Inc. Write for complete details today. Bulletin Kd-289.

High Frequency

The well-known Ajax-Northrup electric furnaces are excellently cataloged in a 22-page book, which covers all sizes and types for laboratory or shop. Includes illustrations, diagrams, tables and charts. Ajax Electrothermic Corp. Bulletin Ia-41.

Turbo-Compressors

Spencer Turbine Co. has turbo-compressors in all sizes and types for oil and gas-fired furnaces, ovens and foundry cupolas. Special types for special purposes such as gas-tight and corrosion resisting applications are also described in Bulletin Da-70.

More literature listed on following page ⊂

HELPFUL

Firestone

A story of the origin and history of Buckeye silica firestone makes an interesting preamble to a complete technical discussion of the properties and applications of this refractory. Cleveland Quarries Co. Bulletin Ka-176.

Super Refractories

A catalog of Chas. Taylor Sons Co. is replete with useful data on P. B. Sillimanite refractories for use up to 3300° F. in electric furnace roofs and linings, induction furnaces, crucible furnaces, fuel-fired hearths, piers and linings, burner blocks, etc. Bulletin Ec-218.

Steel • Iron

Ground Shafting

A colorful folder describing Ground Shafting made by Bliss & Laughlin, Inc., is now available through this company. Pictures steps in shafting production. Bulletin Bc-42.

Stainless-Clad

IngAclad Stainless-Clad Steel is covered in detail by a new booklet issued through Ingersoll Steel & Disc Division, Borg-Warner Corp. Bulletin Kc-253.

Recommended Tool Steels

A new chart giving the brands of Jessop tool steels recommended for various tools, dies and other applications, has just been released by the Jessop Steel Co. Bulletin Ic-173.

Vanadium Steel

Latrobe Electrite Vanadium High Speed Tool Steel is described in literature released by the Latrobe Electric Steel Co. Bulletin Kb-208.

Special Alloy

"Five-Point" Deephard steel produced by a special process is completely described in a 12-page folder made available by Foote Bros. Gear and Machine Corp. Bulletin Hc-244.

N-A-X

New twenty-page, fully illustrated booklet on N-A-X high tensile low alloy steel has just been published by Great Lakes Steel Corporation. This steel has been thoroughly proved in application where ordinary high tensile steels have failed. Bulletin Kd-229.

Special Steels

An impressive new 160-page Hand Book of Special Steels which gives the very latest data on the characteristics and applications of Allegheny Ludlum tool steels has just been printed. Write today since issue is limited. Bulletin Ic-92.

Machine Tool Castings

A completely illustrated 16-page booklet containing applications of Meehanite castings in the machine tool industry has been prepared by the Meehanite Research Institute of America, Inc. Bulletin Kd-165.

Steel Data Sheets

Wheelock, Lovejoy & Co. gives analyses, physical properties, heat treating instructions, and applications of Hy-Ten, Economo, and S.A.E. alloy steels in concise and easily usable form. Bulletin Ox-74.

Unusual Casting Metal

An unusual type of casting metal which bridges the gap between malleable iron and steel is described in a new folder by Chicago Malleable Castings Co. Bulletin Kd-279.

Stainless Stock List

The large mill stock of stainless steel bar and wire carried for immediate shipment by the Rustless Iron and Steel Corporation is itemized in a new stock list released by this company. Bulletin Gd-169.

High Speed Steel

Required hardness and extraordinary toughness combine to make Firth-Sterling Steel Co. new high speed Steel "Mo-Chip" of unusual interest to manufacturers who need a steel that is "practically indestructible." Bulletin Ad-177.

Tool Steels

Information about the fine steels made by the Uddeholm Company of America, Inc., can be obtained by requesting their new bulletin. This company controls its output completely from the ore mine to the consumer. Bulletin Eb-196.

Free Machining Steels

Speed Case and Speed Treat, two steels with increased machining properties, are described in literature available through Monarch Steel Co. Bulletin Cd-255.

Steel Data

Ten colorful leaflets each describing a popular grade of tool or high speed steel and giving useful data, application information, etc., have just been issued by Vanadium-Alloys Steel Co. Write for Bulletin Kd-294.

Trantinyl

"Ten times the wear"—"Turn after turn untouched"—"Unbelievable tonnage and low scrap"—are a few of the comments by users of Trantinyl alloy guides. The answer is the right choice of over 22 alloy steel analyses plus correct processing and heat treating by Youngstown Alloy Casting Corporation. Operating men should investigate this amazing alloy now. Bulletin Kd-291.

Free Machining

Reserve your copy of new twenty-page story of Speed Case and Speed Treat. This new booklet covers physical properties, compares this W. J. Holliday & Co. steel with SAE 10-20 and others. Explains how manganese and sulphur content plus patent manufacturing processes produce free machining combined with comparatively high physical values. Also contains machinability carburizing tables and pictures applications. Bulletin Kd-293.

Finishing • Plating

Degreasers

An interesting line of portable degreasers which can be taken to the work—instead of bringing work to the degreaser—is shown and described in a colorful folder by the Phillips Manufacturing Co. Bulletin Nc-254.

Chemicals

A complete line of Fluxes, Inhibitors, Zinc, Alkali Cleaners and Acids is described in a new catalog issued by Grasselli Chemicals Dept. of E. I. DuPont de Nemours & Co. Bulletin Dd-95.

Metal Blackout

The new JETAL process for blackening iron and steel quickly and thoroughly at low cost is described in literature available through the Alrose Chemical Co. Bulletin Cd-256.

Cadmium Plating

Concise, practical information for the operating plater is included in an up-to-date manual on cadmium plating released by E. I. DuPont de Nemours & Co., Inc. Bulletin Hd-29.

Rotoblast

Quicker production Blast Cleaning Equipment for producers of metal castings, forgings and heat treated parts is explained in literature just released by the Pangborn Corp. Bulletin Ic-68.

Mounted Wheel Chart

A convenient ready reference wall chart showing mounted grinding wheels should be of great advantage in the cleaning room, pattern shop, tool and die room, and many other places. It gives at a glance, by means of detailed drawings, actual size, the exact radius of each wheel and its exact shape. Chicago Wheel & Mfg. Co. Bulletin Bd-230.

Degreaser

Degreasing machines for practically every cleaning job are described in literature made available through the Detroit Rex Products Co. Bulletin Hc-111.

Welding • Cutting

Kickless Cable

A water cooled electrical connection between the secondary taps of a welder transformer and a portable welder gun is described in a new bulletin by the Clark Controller Co. Guaranteed not to tangle or "kick". Bulletin Kd-280.

Brazing Alloys

How you can put your metal joining on a sound, economical basis is explained in a folder just released by Handy & Harman. Well illustrated and full of facts. Bulletin Ic-126.

Welding Stainless Steels

A 24-page technical bulletin, giving important information for the engineer, designer or welding operator on the welding of stainless steel, is available through the Arcos Corp. Bulletin Hc-191.

Welding Stainless

How to weld stainless steels is described in a colorful 12-page folder released by the Page Steel and Wire Division of American Chain & Cable Co., Inc. Bulletin Cc-86.

Flame Gouging

An economical method of grooving steel, "Flame Gouging", is explained with operating data and illustrations in an 8-page folder released by The Linde Air Products Co. Bulletin Bd-63.

Non-Ferrous Metals

Copper Bulletin

A new clearing house for news of developments in brass, bronze and copper, the "Copper Alloy Bulletin", issued by the Bridgeport Brass Co., made its appearance with the March issue. It is edited for the technical and engineering audience. Bulletin Da-163.

Ampco Alloys

A new booklet covering "Ampco Alloys in Pump Service" is being released by Ampco Metal, Inc. Bulletin Gd-175.

Extrusions and Pressings

The book "Impact Extrusions and Pressings" showing many impact extrusions made of Alcoa Aluminum Alloys, for designers and production men, is available through the Aluminum Company of America. Bulletin Hc-54.

LITERATURE

Structural Metal

A complete and concise discussion of magnesium and its alloys is contained in the booklet "Industry's Lightest Structural Metal" which is made available through the Dow Chemical Co. Bulletin Bd-215.

Melting • Casting

Ingot Production

"The Ingot Phase of Steel Production" is the title of a book defining the principles of quality ingot production followed by many well-known steel manufacturers. Gathmann Engineering Co. Bulletin Ka-13.

Foundry Sand

A pamphlet recently issued on TAM Foundry Zircon Sand and TAM Zircon Flour contains detailed information on these products of the Titanium Alloy Mfg. Co. Bulletin Hc-90.

Pit Handbook

A virtual handbook on soaking pit procedure best describes the new booklet published by Amsler-Morton Company. Included are comprehensive case histories of pits now in successful operation. Bulletin Kd-286.

Ferro-Alloys

An interesting folder by Electro Metallurgical Co. tells all about their ferro-alloys and their special service to users which will help them to operate their furnaces and make alloy additions under the proper conditions. Bulletin Jy-16.

Vanadium Castings

A 24-page bulletin well illustrated with more than 20 photographs contains a complete description of the properties and applications of a number of vanadium alloy steels for castings where high strength is required without excessive weight or high cost. Vanadium Corp. of America. Bulletin La-27.

Testing • Control

Multi-Point Pyrometer

The Alnor Rectangular Type Pyrometer, designed to provide a rugged moderately priced instrument with multi-point switch, is described in a release by the Illinois Testing Laboratories, Inc. Bulletin Dc-180.

Comparator-Densitometer

A unit for accurately and speedily projecting a spectrogram on a viewing screen and enabling positive spectral lines identification up to 70 elements is covered by a new folder released by Harry W. Dietert Co. Bulletin Kd-198.

Testing Machines

A compact spiral-bound 58-page booklet on the extensive Olsen line of testing machines and instruments has just been released by the Tinius Olsen Testing Machine Co. Well illustrated and filled with informative charts and testing data. Bulletin Gb-147.

New Gages

Catalog describing the new gages which shops are using to control the dimensions of shell, gun and airplane engine parts is presented by Federal Products Corporation. Bulletin Kd-292.

Temperature Determination

A new device for determining temperatures in industry, consisting of little thermometric pellets called "Tempils" is explained and illustrated in an attractive folder printed by the Tempil Corp. Bulletin Fd-270.

Surface Analyzer

Instantaneous and permanent chart records of irregularities in finished surfaces such as metals can now be made with the Brush SA-2 Surface Analyzer and is completely described in booklet by the Brush Development Company. Bulletin Kd-288.

Control Instruments

The general Wheelco catalog illustrating this famous line of control instruments is now available through the Wheelco Instrument Co. Bulletin Kd-110.

Wide-strip Pyrometer

Complete information on the new Bristol Multiple Record Wide-Strip Pyrometer can be obtained through the Bristol Company. Gives up to 8 temperature records on the same chart. Bulletin Ac-87.

Metal Working • Forging

Hard Facing Alloys

For maximum resistance to wear and corrosion, the Wall-Colmonoy Corp. offers a fact-packed folder which is extremely helpful to anyone having this problem. Bulletin Kd-85.

Rotary Files and Burs

A variety of high-speed Rotary Files and Burs plus other necessary shop equipment is included in the complete catalog available through the Martindale Electric Co. Bulletin Kd-282.

Drop Hammers

Erie Foundry Co. has an illustrated bulletin giving complete information on modern practice with steam drop hammers. Bulletin Jy-130.

Kennametal Tools

A new booklet telling how to cut steel profitably with Kennametal tools and blanks is offered by McKenna Metals Co. Bulletin Kd-238.

Cutting Alloy

New price sheets released by the Carboloy Company will be interesting to men concerned with machining problems. Bulletin Kd-278.

New Machines

The Acme Machinery Company has just published two catalogs, one describing Acme Model XL Threading Machines, the other describing Acme Model XN Forging Machines. Both announce the new Model XR Roll Threading Machine, which rolls threads on bar stock up to 1½-inch diameter in any length. Bulletin Kc-39.

Cutting Oils

An interesting new booklet, "Metal Cutting Lubrication — In Theory and Practice", has just been made available by Cities Service Oil Co. Bulletin Ec-113.

Heat Resistant Metals

Alloy Castings

The "extra point" value of Michiana alloy castings is shown in a booklet released by the Michiana Products Corp. Typical installations are shown. Bulletin Nb-81.

Refinery Alloys

Special alloys for refineries, corrosion, temperature, and abrasion resisting are covered in a colorful folder produced by the Duraloy Co. Bulletin Kd-233.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Metalwove Belts

Metalwove Belts used in a wide range of applications heretofore believed impractical in the continuous treatment of metals are illustrated and described in a new catalog released by Audubon Wire Cloth Corp. Bulletin Kc-250.

Centrifugal Iron

A bulletin descriptive of the recent development and production of centrifugally cast alloy irons, Ni-Resist, and other compositions by Shenango-Penn Mold Co. includes the chemical analysis, physical properties and uses of four standard gray iron compositions. Bulletin Ka-174.

Pyrasteel

All types of uses for Pyrasteel, the heat resisting alloy made by Chicago Steel Foundry Co., from astronomical plaques ruled 20,000 lines to the inch to huge kilns, are described in an illustrated pamphlet. Bulletin Cb-184.

Fahralloy

Complete and interesting information about the alloy castings and other Fahralloy Company products may be obtained in an attractive new leaflet. Bulletin Hb-199.

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Lc-145	Ea-5	Hc-226	Kd-289	Kb-208	Eb-196	Ic-68	Da-163	La-27	Ac-87	Ec-113	Cb-184
Cd-43	Oy-114	Ga-168	Ia-41	Hc-244	Cd-255	Bd-230	Gd-175	Dc-180	Kd-85	Nb-81	Hb-199
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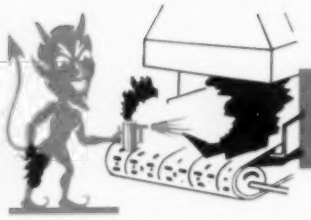

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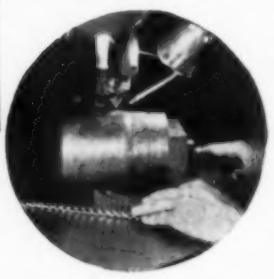

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metal progress

steels & irons

4140 GOES TO SEA

It is well for all concerned that builders of marine Diesels make performance capacity the primary basis for the selection of materials. Breakdowns at sea or anywhere else are no fun for anyone, including the engine builder.

But the demand for reliability can be met and production costs still kept where they should be. One prominent builder, for example, is doing both by specifying Chromium-Molybdenum (SAE 4140) steel for a number of parts including bolts, wrist-pins, cylinder head studs, gears, tappets and crankshafts.

The fact that this steel can be treated to develop the properties necessary for applications having such different requirements is of value to both builder and user. It simplifies heat treatment and stockroom procedures. And, since simplification makes for uniform quality in the finished parts, it gives added assurance of dependability.

Your own product might benefit through the use of this versatile steel. You will find complete data on this and other molybdenum steels in our book "Molybdenum in Steel," which will be sent free on request.

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Steels and Irons

Supplies of Manganese (an Essential for Steel Making)

By R. C. Allen
Consultant for Manganese
The Advisory Commission to the Council of National Defense

WE in the United States are not facing an immediate emergency so far as concerns supplies of manganese. At the present rate of consumption we have approximately 16 months' supply in the country, and imports are coming in at about the current rate of consumption. Russia is cut off, but sources in India, Africa, Cuba, South America, and the Philippine Islands are available and are being utilized to the extent shipping is available. Definite plans are under way for supplementing imports through domestic production of ore suitable for the manufacture of ferromanganese; this is a matter of vast detail, but progress is being made. In August a contract was signed with the Anaconda Copper Mining Co. for the delivery of 80,000 tons of manganese concentrates per year from proven ore reserves in the Butte mines. A relatively small tonnage of high grade manganese ore is available from domestic deposits without concentration. However, it will take some time to plan for production and to get production under way in the several districts in the country containing low grade deposits of considerable magnitude.

Steel and Iron Castings

By Edwin Bremer
Metallurgical Editor, "The Foundry"

PRESENT EFFORT in the foundry field essentially is devoted to improvements in melting and molding practices in order to produce high quality castings on the most economical basis. The search for new alloys is counteracted by a growing tendency to investigate more thoroughly the properties of those in use for some time so as to obtain all possible information on their potentialities; this interplay of influences actually results in fewer compositions meeting a wide range of applications. However, there is no pause in the development of new combinations with specific properties to meet special applications.

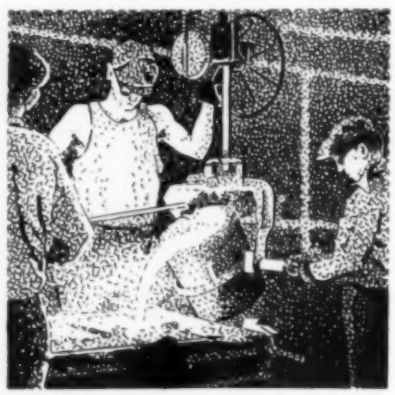
In the steel castings field other and cheaper methods are replacing dry sand molding. In green sand more resistance to cutting at or near the gates is being secured, and other refractories than silica — for example, zirconia or aluminum silicates — are suggested for vital points. Differential heat treatments continue to develop. Flame hardening is opening up new avenues of application previously closed to steel castings. Many factors point to a revival of the converter as a melting medium; such factors include a continuing small price spread between scrap and pig without any reduction in electric power cost, the advantages of a hot-blast cupola, improvements in desulphurizing cupola iron, and the photoelectric control of the converter flame.

Low alloy steels are meeting objectively two requirements. On the one hand they are providing more stability and ruggedness to standard designs without any weight saving. On the other hand, the advantage of superior physical properties is being exploited to decrease weight. Shapes and location of inclusions formed as deoxidation products have been recognized as important factors in determining the physical properties of steel castings, and new deoxidizers now available greatly aid the foundryman in producing uniform and predictable properties. Exothermic processes show possibilities; one applies the thermit reaction to produce stainless steel castings from stainless scrap, ferrochromium and nickel; another utilizes a silico-thermic reaction to produce molten ferrochromium in the ladle or in the furnace. Recoveries of 90 to 95% are claimed, as well as lower cost through shortening of time of heat,

alloying without chilling, and greater flexibility and accuracy in alloying. Successful application of centrifugal casting to automotive cluster gear blanks and ring gear blanks undoubtedly will lead to further use of the method in similar shapes desired on a quantity basis. Steel foundrymen no longer need fear aspersions reflecting on the weldability of steel castings, particularly in combinations of cast and wrought structures, since a recent investigation proves beyond doubt that cast steels show at least as good, and in many cases better, weldability than comparable rolled products.

In the gray iron field, including both plain and alloy types, there has been no let-up in the investigation of better production methods. More and more data are being made available to show the dependability of iron castings in engineering and other fields. Progressive foundrymen, keeping closely in touch with such developments, are enabled to supply customers with a wide range of compositions to meet a broad field of applications ranging from those requiring high damping capacity to those necessitating strengths approaching and sometimes exceeding other materials, not to mention heat and wear resistance. Use of alloys is being given critical consideration; such use is increasing where service and economy warrant. Heat treatment for stress relief and for improvement of machinability is being extended, as it is also for obtaining high hardness for wear resistance, and for an improvement in physical properties.

Oxy-acetylene flame heating for selective hardening — particularly of gray iron — is being employed more and more, and increasing thought and attention are being accorded to induction heating and quenching for producing high surface hardness. A process similar to austempering of steel, involving quenching in a molten bath maintained at 550 to 750° F. for 15 to 30 min. is claimed to result in greatly improved physical and wear resisting properties for the casting.



In the malleable field every effort is bent toward maintaining high quality through close control of various production phases from melting to finished casting. A few foundries are producing a high strength malleable having on the order of 64,000 psi. tensile strength, 49,000 psi. yield, and 20% elongation; this is had by the addition of molybdenum to an otherwise regular composition. In production shops some increase is noted in the use of duplexing, and also an improvement in procedure. Use of pearlitic malleable cast irons continually is expanding in applications requiring high shock resistance with high elastic limit, good wearing qualities, high fatigue resistance and good machinability. Pearlitic malleable castings have replaced numerous forgings, particularly in the automotive field; quenching in a molten bath similar to austempering has been suggested as a further improvement. Short cycle annealing seems to be holding its own, and apparently its expansion is essentially one of economics.

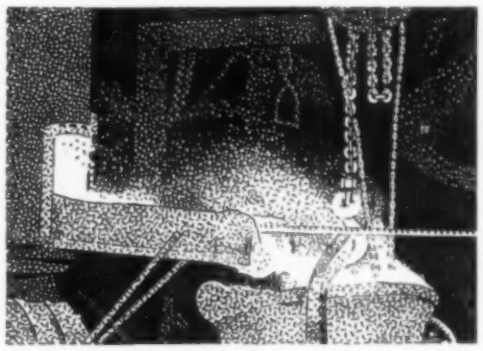
Ladle Additions to Cast Iron

By Richard Schneidewind
Asso. Prof. of Metallurgical Engineering
University of Michigan

IRON-CARBON-SILICON alloys, such as are commonly found in commercial gray and white cast irons, are more susceptible, perhaps, to undercooling and rate of cooling than any other common material. If we change the rate of cooling of steel from the molten condition, the only difference in result that could be noted would be a refining of the grain and a difference in the product of the transformation of austenite. Cast irons also are finer grained if rapidly cooled and the austenite will likewise transform as martensite. In addition, however, these alloys have the ability to freeze in one of two systems — either the Fe_3C-austenite or the graphite-austenite system (see the equilibrium diagram, page 422). Probably everyone knows that if an iron-carbon-silicon alloy is very rapidly cooled, the resulting product is white iron consisting of cementite plus pearlite or other decomposition products of austenite, whereas if slowly cooled, the cementite is replaced by graphite.

To illustrate this principle, a casting may be made in the form of a wedge with a 12° angle. White iron will be found at the point of the wedge; as it gets thicker and the cool-

ing rate slower, a mottled zone of ferrite, graphite, carbide, and pearlite is reached. As the cooling rate becomes still lower we eventually obtain various forms of gray cast irons containing graphite and pearlite and, in very heavy sections, graphite and ferrite. If such a wedge were sectioned and its hardness explored one would obtain greater than Rockwell C-50 at the tip. Hardness drops off as the amount of cementite decreases and at a critical cooling rate midway between one giving white iron and one giving gray iron there is a zone of very low hardness (about C-8). In this zone, about ¾ in. from the tip of the wedge, the matrix structure is ferrite. The presence of such ferrite is very harmful, particularly if the iron is to be used for metal-to-metal wear, as in a piston ring. At about 1¼ in. from the tip the iron is harder (C-14) and then softens up to C-9 or 10 at the butt of the wedge.



The precise locations of these various zones are somewhat dependent upon the chemical analysis; for example, a high carbon, high silicon iron will give a small amount of white iron, and gray iron is found at much faster cooling rates than with the low carbon and silicon. The chemical composition of gray cast irons, however, is a much less certain criterion of the structure of the iron than would be the chemical composition of a steel. The nature of the cast iron is profoundly influenced also by such things as the nature of the raw materials used, the furnace used in melting, the cooling rate, and finally the condition of the melt. By "conditions of melt" is meant the degree of oxidation or perhaps the gas content.

Ladle treatment has long been used to modify the properties of gray cast irons. It is necessary to use only small quantities of ladle alloys, quantities insufficient appreciably to change the chemical composition. It was known many years ago that less than 0.10% of graphite thrown into the ladle would reduce the amount of white iron obtained, yet if graphite were placed in the charge during melting there is no such behavior. A similar result can also be secured by small amounts of ferrosilicon. A small amount of steel turnings has a reverse effect. One patented process makes use of calcium silicide; this is so effective that if used in a melt of malleable composition, the resulting iron will be gray instead of white.

Alloys widely used for ladle treatment are carbon and ferro-alloys of silicon, titanium, calcium, and zirconium. Aluminum is very effective but promotes the formation of pinhole cavities. Most of these alloys might be looked upon as deoxidizers, which do not stabilize the carbides. Chromium and vanadium, on the other hand, are strong deoxidizers but stabilize the carbide and hence are unsuited for this purpose; such materials may be used for their alloying effect.

The trend in modern ladle treatment alloys is to balance alloys having this graphitizing effect with alloys which are carbide stabilizers; for example, an alloy may be compounded of calcium, silicon, chromium and manganese. With them we obtain not only a reduction of chill and hence better machinability in the light sections, but also, due to the presence of chromium and manganese, an increased stability of the pearlitic carbide so that in the heavy sections the cementite of the pearlite

Influence of Ladle Additions on a Common Gray Iron

Addition	Transverse Breaking Load, Lb.	Deflection, In.	Tensile Strength Psi.	Modulus of Elasticity Psi.	Brinell Hardness	Impact, Ft-Lb. *(a)*	White Zone on Control Wedge, In.
None	2145	0.246	33,050	15,625,000	185	27.5	0.40
0.0264% graphite	2325	0.280	34,675	15,600,000	194	27.5	0.20
2 lb. per ton alloy. *(b)*	2705	0.297	40,700	16,825,000	202	36.0	0.15
2% steel turnings	2215	0.217	32,975	16,200,000	199	20.0	0.45

(a) Impact on unnotched bar, 6 in. long, 1 in. diameter.
(b) Alloy contains titanium, aluminum and silicon; amount used is equivalent to an addition of 0.05% aluminum.

Method for Identification of Inclusions in Iron and Steel

Originated by Wm. Campbell and G. F. Comstock (Proc. A.S.T.M., Vol. 23, p. 521) and Modified by C. R. Wohrman, Merrill Scheil and Miss M. Baeyertz

Polish Specimen Carefully so as to Preserve Inclusions and Project Magnified Image on Ground Glass by Arc or Equally White Light Without Color Screen

Gray or Black Inclusions

Etch 10 sec. with 10% nitric acid in alcohol

Strongly Attacked
LIME COMPOUND *from mold wash (rare)*

Unattacked
Etch 5 min. with 10% chromic acid in water (Be careful to observe that the polished surface is wetted by the solution)

Weakly Attacked *(slightly pitted or darkened)*
COMPOUND OXIDE: *(a) either* FeO *with* FeS *in solution (usually accompanied by* FeO-FeS EUTECTIC*), or (b)* FeO+MnO *and other* OXIDES *in solution*
Note 1: Octahedral crystals are probably MAGNETITE.
Note 2: Both (a) and (b) will be darkened further by 20 sec. sulphur printing (2% H_2SO_4 *in water) and destroyed by etching with stannous chloride as indicated below*

Inclusions of Warm Colors

Etch 10 min. with boiling alkaline sodium picrate

- **Attacked** IRON SULPHIDE *(pale yellowish)*
- **Unattacked**

Etch 10 min. in 20% aqueous solution of HF

- **Attacked:** *Removes* ZIRCONIUM NITRIDE *(yellow cubes) and* ZIRCONIUM SULPHIDE *(tan crystals)*
- **Unattacked** *Inclusions in high chromium steels*

Etch 5 min. in boiling 10% H_2SO_4 + 1% $KMnO_4$, & lightly repolish*

- **Unattacked**
  CHROMIUM OXIDE *(purplish gray by reflected light, bright green by transmitted light)*
  TITANIUM NITRIDE *(yellow cubes)*
  TITANIUM CYANO-NITRIDE *(pinkish; strongly angular, easily pitted in polishing)*
- **Attacked**
  CHROMITE $Cr_2O_3 \cdot FeO$, *isotropic; red to brown by transmitted light*

* *Note: Suitable only for stainless steels with clean (unoxidized) surfaces.*

Attacked

FeS-MnS, *rich in* MnS. *Note: Reaction not always decisive. Any unattacked* FeS-MnS *will be blackened by next treatment*

Unattacked

Note color: (1) Very faint pale grey, (2) Medium or dark grey, and etch 5 min. with boiling alkaline sodium picrate

- **Completely Blackened**
  (1)* FeS-MnS, MnS *below 50%*
  (2)* FeS-MnS, MnS *above 50% or* OXIDE *very rich in* MnO
  ** Refer to color before etch*
- **Partly Attacked**
  (a) OXIDE *rich in* MnO *(will be destroyed by stannous chloride)*
  (b) SILICATE *with some* MnO *(will be destroyed by hydrofluoric acid)*
- **Unattacked**
  (or partly attacked in previous treatments) etch 10 min. with a saturated solution of stannous chloride in alcohol

Attacked

IRON OXIDE *or (if previously pitted)* COMPOUND OXIDE

Unattacked

(or previously pitted) etch 10 min. with 20% aqueous solution of hydrofluoric acid.

Attacked

SILICATE *(if previously pitted presence of* Mn *is indicated)*

Unattacked

Repolish and note color and form

If fine particles, very dark color, difficult to polish without pitting and not elongated by hot work is ALUMINA

If color not especially dark, easily polished smooth without pitting

Fairly large angular fragments, showing changeable bright spots as focus is changed, are SAND GRAINS *(in steel castings)*

Small angular particles, bluish in color probably TITANIUM OXIDE *(in titanium treated steels)*

Supplementary Tests

In all instances check determinations in the light of the evidence of a careful chemical analysis, and, whenever possible, by other methods, such as:

I Sulphur Printing

(for 20 sec. using a 2% aqueous solution of H_2SO_4*)*
(1) Dissolves all FeS-MnS *inclusions*
(2) Partly dissolves (pits) FeO *containing* FeS *and* OXIDES *of other metals in solution*
(3) Leaves unchanged: IRON SULPHIDE *(pale yellow),* pure IRON OXIDE *(medium grey),* SILICATES *(dark grey)*

II Matweieff's Tests

(a) Dilute tartaric acid does not attack OXIDES *or* SILICATES, *but colors* MnS *lightly and* FeS *decidedly*
(b) Heat sample in hydrogen at 1600°F., OXIDES *are reduced,* SILICATES *and* SULPHIDES *are unaffected*
(c) Repolish (b), etch with dilute $FeCl_3$ *in alcohol; if reduced oxide particles are colored deeply they contain some* Mn

III Rohl's Test for Sulphides

Short etch with 1% picric acid in alcohol, then temper to dark yellow.
FeS *turns dark blue to reddish violet, and* MnS *turns dull grey to bright white.*

does not decompose into graphite and ferrite. Thus, the light sections are rendered softer and more machinable, and the heavier sections are rendered stronger. A casting with non-uniform section size and hence different rates of cooling can be obtained with more nearly uniform mechanical characteristics throughout. In addition the shape of the graphite can be controlled to produce a metal with maximum strength and wear resistance.

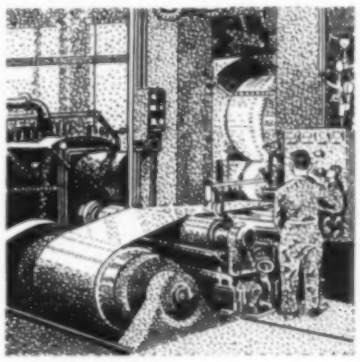
At the bottom of page 375 is a table showing the influence of various ladle treatments on a single melt of gray iron melted in a Detroit electric furnace and poured into standard transverse "B" bars. The chemical composition of all specimens was 3.10% C, 2.12% Si, and 0.69% Mn. Successive ladles of the melt were given the treatments indicated.

Sheet Steel

By R. S. Burns
Research Engineer
The American Rolling Mill Co.

THERE IS NO NEED to point out that the practice of rolling wide sheet steel in long coils on hot strip mills, and its subsequent reduction to gage in continuous cold rolling mills, has almost entirely superseded the hand-mill practice prevalent 20 years ago. Even as recently as 10 years ago a 19-gage sheet 60 in. wide was uncommon and the losses connected with its manufacture were very high. In those days "high finish" sheets were being rolled on hand hot mills from 8-in. sheet bar. Such mills are now operating only to supplement hot strip mills when extra width is demanded, or where equipment retirement plans have not yet decreed their abandonment.

From 1928 to the present time it has been the problem of the steel mills to give to the sheet fabricator — and particularly the automotive industry — all the wide sheets required. It was formerly the practice to make the rear quarter of an automobile body in a number of stampings, such as the upper quarter panel, the lower quarter panel, the wheelhouse panel, and roof rail, which were fastened together in various manners, usually by welding, and the joints covered with decorative trim.



Present practice is to use wide sheets and eliminate as many welds and operations as possible, as is evidenced by the single stamping now being used for a rear quarter panel. In some body works a complete side panel is made in one stamping. Fenders once were made in two pieces (a crown and apron); they are now being made in one piece and include the hood ledge and the headlamp section. Another notable new use of wide sheets since 1935 is in the one-piece drawn steel top. This was pioneered by Fisher and is now practically standard equipment on closed cars. Not many years ago such a stamping would have been impossible, both from a sheet and a press standpoint.

Another present-day trend in the automobile body fabricating industry is toward the use of "sheets in coils", or wide strip coils, in order to blank irregular shapes with less scrap loss than would be possible from rectangular sheets. Parts being made from wide coils now include side panels, radiator shells, front and rear fenders, hood tops, hood sides, and running boards.

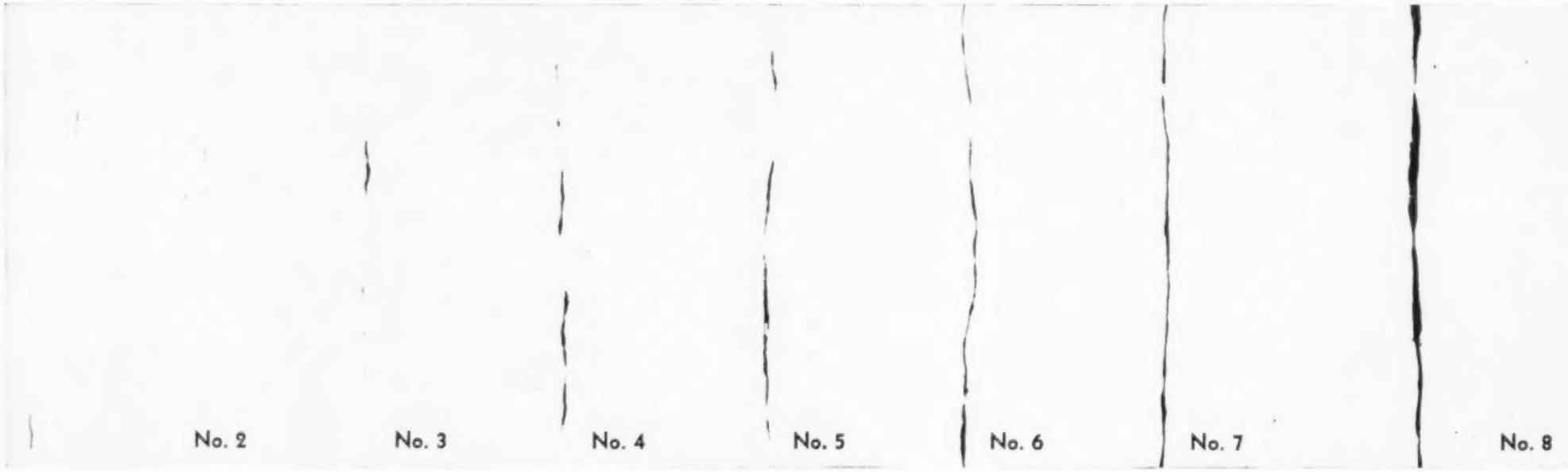
It is general sheet mill practice for mill representatives and metallurgists to work closely with body builders, so that any slight adjustments in sheet production methods can be made as the need arises. This enables the mill to understand clearly the customer's requirements and make changes in processing of material to meet specific requirements. In most cases the cooperation between the fabricator and the mill has been so complete and satisfactory that it has been found unnecessary to write restrictive specifications covering the physical properties and chemistry of the sheets. The main requirement is that the steel should be satisfactory for the job insofar as breakage, surface after drawing, and defective metal are concerned.

As is frequent where rapid progress has been made, the art has preceded the science; were it not for the wholehearted cooperation of the body fabricators and stamping plants, it is doubtful that the development of wide drawing sheets would be as far along as it is. Installation of processing levelers of the conventional type, and of the Budd-McKay type, has made it possible to use sheets having a tendency to stretcher strain, arising from slight under-tempering at the mill or from the effects of aging.

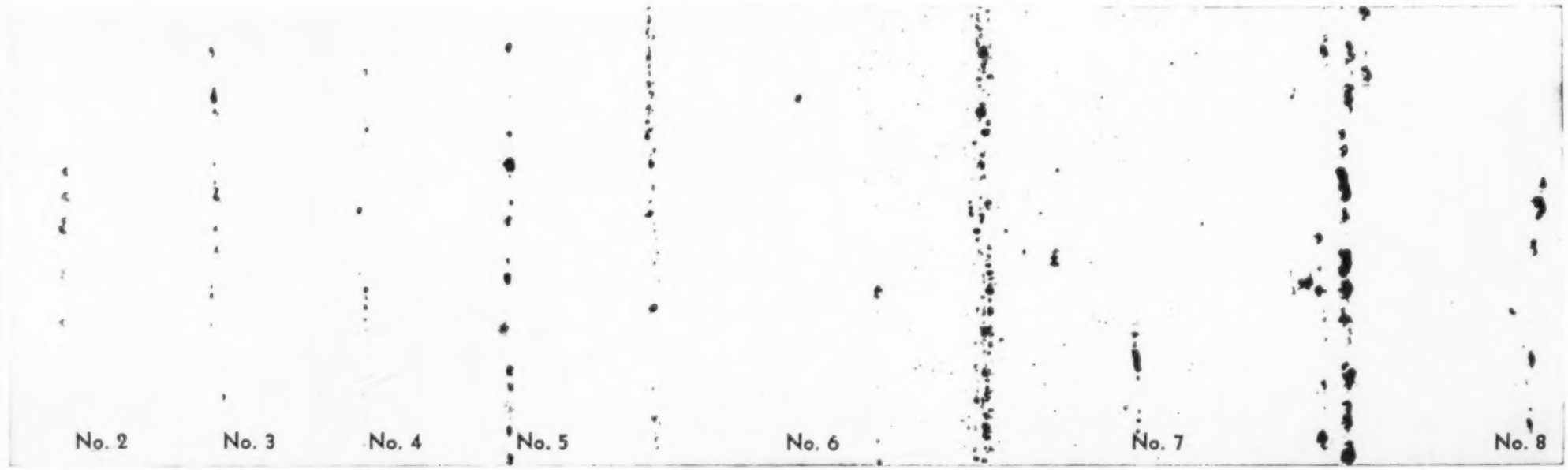
Sheet manufacturers are

Rating of Inclusions ("Dirt Chart")

In use by Chevrolet Motor Co. *Developed by George W. Walker*



Silicate Slag Inclusions



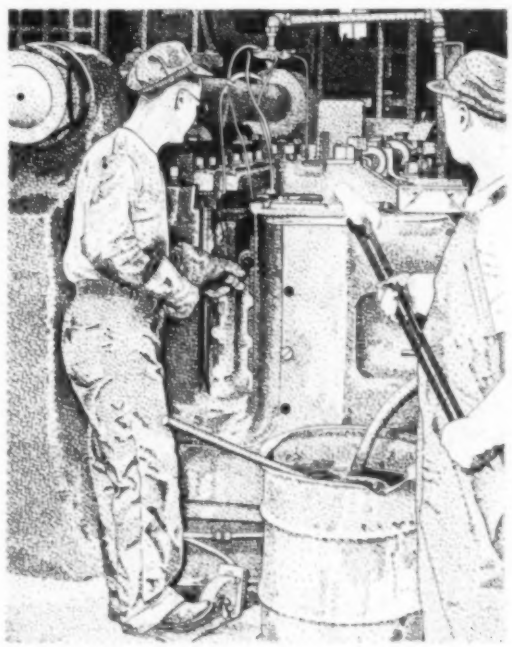
Oxide Inclusions

continuing to meet new requirements and to improve present construction. There is much work yet to be done in the steel plant and rolling mill to produce better drawing sheets. By the use of killed steels which are free from aging (the manufacture of which was developed by the American Rolling Mill Co.), sheet users are now able to obtain sheets which will not only make more difficult stampings but which reduce the scrap loss on moderately hard jobs to the vanishing point.

Better Carbon Steels

By Roy W. Roush
Chief Metallurgist
The Timken-Detroit Axle Co.

IN THE EARLY DAYS of the automotive industry, when production began to show rapid increases, economy with respect to materials was a minor consideration. The demand was for the best, regardless of the cost, and carbon steels gave way to alloy steels in all important applications. No doubt, some higher alloy steels were used in places where their full value was not needed, but their increased properties and their better response to heat treatment made them superior to carbon steels. Parts could be made smaller and lighter, allowing greater speeds and economies in power. While in some cases the use of alloys covered a multitude of sins, the steel makers got a higher price and took greater care in alloy steel making, and developed methods and processes which gave assurance of higher quality and greater uniformity. Additional work, better control in the steel mill and the exercising of greater care introduced the term "alloy practice".



As the industry advanced, as competition became keen and as margins of profit became narrower, increasing demands for economy began to limit the use of expensive alloys. Efforts were made to produce the same quality by this so-called alloy practice and by improved treatment, but with limited amounts of alloy. Each year has seen reductions in the amounts, and the use of cheaper alloys and combinations. Steel costs have been lowered materially in this way and the number of important automotive uses requiring large quantities of high alloy steels is diminishing.

The past year has seen a concentration of effort in steel making toward higher quality and lower costs. Strange as it may seem, the results shown to date take us a step nearer to the prediction that alloy steels would give way to carbon steels for a number of important uses. We do not, however, have reference to the carbon steels of the early days. The ever-popular term, "alloy practice," is in the picture, together with some of the recently developed medicines or treatments which have to do with deoxidizing the steel. Reference is here made to ladle additions of vanadium, titanium and aluminum, a treatment which has been developed after much investigation of deoxidation methods. It is used chiefly on openhearth steels of the manganese type (S.A.E. 1300 series) and of the straight carbon type. If smaller amounts are wanted than a complete heat, single ingots are so treated.

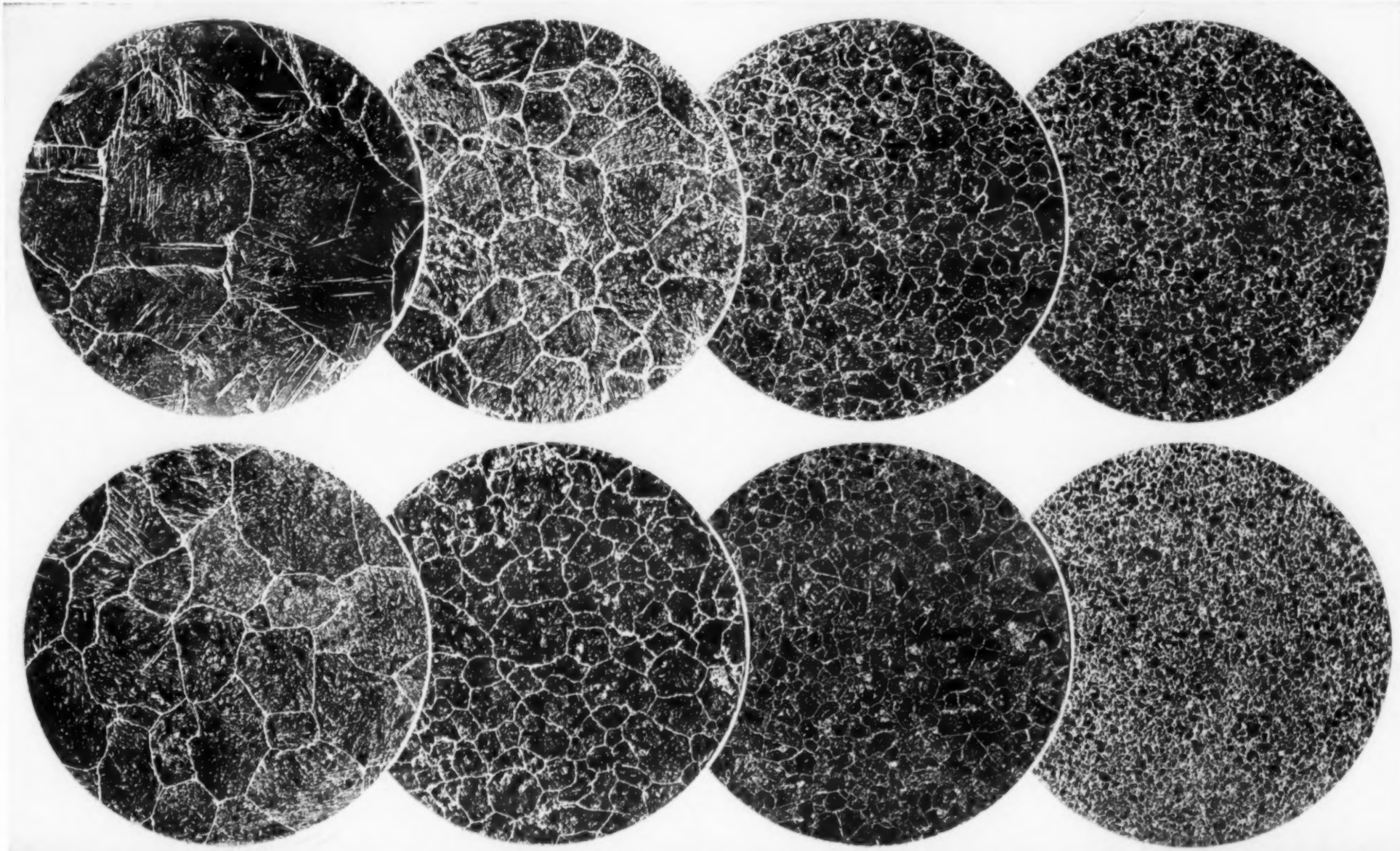
This treatment, which is said to be very effective in removing oxygen and nitrogen, has been proven to give much better physical properties to such steels. Its effect has been best in the higher hardness ranges and seems to fade out in the lower ranges. It is used on structural steels and on carburizing grades. The actual amount of these refining elements found in the final product is in the neighborhood of 0.05%.

Manganese and carbon steels which have been so treated exhibit greater hardenability and decidedly increased ductility. They are not only fine grained and normal but are very uniform in crystalline structure. Impact values and fatigue properties are definitely increased — in some cases doubled. Tests have shown that carbon steels after this treatment have impact and fatigue properties exceeding those of fine

Standard Grain Sizes for Steels

Carburized and slowly cooled to develop cementite network. Magnified 100 diameters. Micros courtesy Timken Roller Bearing Co.

Grain Size No. 1; Up to 1½ per sq.in. No. 3; 3 to 6 grains per sq.in. No. 5; 12 to 24 grains per sq.in. No. 7; 48 to 96 grains per sq.in.



No. 2; 1½ to 3 grains per sq.in. No. 4; 6 to 12 grains per sq.in. No. 6; 24 to 48 grains per sq.in. No. 8; More than 96 grains per sq.in.

alloy steels. They have higher strength because they can be heat treated to a higher hardness. They will take a more drastic quench and can be used for a number of structural parts as hard as 600 Brinell. Torsional fatigue tests, under certain conditions, have shown them to be away out in front of anything yet tried. Machining properties are good, without normalizing.

A considerable amount of investigation and research is being conducted to learn more about the nature of this effect and the reasons for such very marked increases in physical properties. One is reminded of the Swedish steels with their great reputations for quality, uniformity and endurance. If we remember, their analyses showed a similar amount of vanadium.

This deoxidation method promises to be one of the outstanding refinements in steel making and offers possibilities for carbon steels beyond what has been realized. While some additional testing will be required before final and complete recommendations are made, carbon steels so treated have certainly exhibited surprising properties and will undoubtedly be widely used in applications now requiring the best steels.

Oil Well Casing

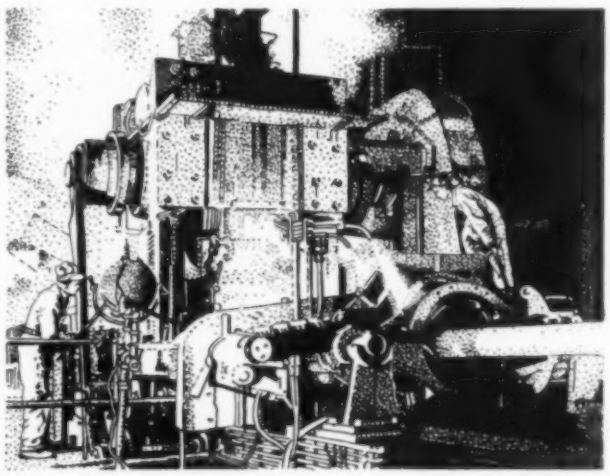
By E. C. Wright
Chief Metallurgist, National Tube Co.

OIL WELLS have reached depths of 15,000 ft. and there are now many producing wells with depths ranging from 10,000 to 14,000. The development of satisfactory pipe to resist the conditions existing at such depths for producing oil is a major engineering problem.

Pipe strings employed in these installations must have extremely high physical properties to resist the great external and internal formation pressures. Joints in the pipe must be leakproof at gas pressures as high as 5000 psi. with sufficient strength to support safely the whole length of the heavy pipe string while it is being set. An example of a 6⅝-in. outside diameter casing string set to 13,000 ft. shows that the stress in the pipe due to collapse at the bottom of the string is 50,000 psi., and the tensile stress in the pipe at the derrick floor due to the weight of the string is 48,000 psi. The pipe necessary for these engineering requirements must be made from materials having a yield strength of at least 80,000 psi.

There are several alloying combinations used to produce this strength in hot-rolled seamless pipe whose physical properties may be further enhanced by heat treatment. The steel must also have good ductility and toughness, as after this pipe is finally set it is frequently subjected to stress from the vibration of drill pipe used to deepen the hole; also to perforations from 45-caliber bullets in order to slot the pipe for oil production from the surrounding oil sands.

A bridge engineer would probably not have much enthusiasm for a structure subjected to repeated dynamic stresses approximating 60% of the yield point. This, however, is common in casing installations, as there have even been instances where casings had a factor of safety against collapse of only one. The high tensile fiber stress of 48,000 psi. would be too much for an ordinary threaded joint to stand, since sufficient metal is cut away from the pipe area in threading to reduce the strength of the material under the threads. This difficulty is overcome by special upsetting of the ends of the pipe, thereby strengthening the ends so the threaded joints exhibit a strength which is greater than the strength of the body of the pipe itself. Therefore, in a deep string such as that described above, the pipe joints (at least in the upper parts of the string which carry the greatest load in tension) would be made of special form. This practice has enabled the successful landing of these very long strings without failures in the joints.



Corrosion Protection by Rust Inhibitors

By Everett P. Partridge
Director of Research
Hall Laboratories, Inc.

THE TREMENDOUS URGE of iron in contact with water to convert itself into rust has occasioned unceasing effort to develop corrosion resistant irons and steels, on the one hand, or protective coatings on the other. The latter have ranged all the way from electroplated deposits and paints of all kinds to those less readily visible (but none the less effective) protective films produced by chemical treatment of the water. In the past, such chemical treatment of water to minimize corrosion has involved the addition of alkalies such as soda ash or caustic soda, or of salts such as sodium chromate or sodium silicate either alone or admixed with organic materials. During the past year a further advance has been made in corrosion control by the use of the sodium phosphate glass known as sodium hexametaphosphate.

When present only to the extent of one or two parts per million in water, sodium hexametaphosphate very greatly retards the ordinary process of rusting, the rate of corrosion being cut down to from 5 to 10% of that which would occur in the absence of the inhibitor. While no visible coating is produced on the metal surface, it is believed that the sodium hexametaphosphate is "plated out" on the surface of the metal, forming a film perhaps only of molecular dimensions. Its efficacy in minimizing corrosion has already been demonstrated on a practical scale in a number of municipal water systems, where "red water" complaints have been eliminated. In agreement with extensive studies in the laboratory, good results have been reported from the field with a natural water with a pH value as low as 5.4, as well as with more alkaline waters.

Corrosion control with sodium hexametaphosphate involves a procedure totally different from the well-known process of building up a visible protective coating on steel by treatment in phosphoric acid baths. To maintain protection in the new treatment it is necessary that the chemical be present substantially continuously in the water in contact with the metal surface. If this requirement is met, the invisible protective film is self-healing, the metaphosphate being adsorbed from solution at any point where metal becomes exposed.

Rating of Aircraft Quality Steels — Magnaflux Inspection

By J. B. Johnson
Chief, Materials Laboratory, Wright Field

THE TERM "aircraft quality" is receiving considerable attention at the present time, since many producers and fabricators of steel are interested in producing aircraft parts in connection with the armament program, yet it is not possible to give it a simple definition. "Aircraft quality" implies that the steel has the requisites for the fabrication of parts for airplanes, engines and accessories of satisfactory properties and uniformity.

The Aeronautical Materials Specifications recently published by the Society of Automotive Engineers incorporate requirements for chemical composition, grain size, physical properties and surface condition, with the additional provision that the material must be "aircraft quality", a statement modified by the requirement that finished parts are subject to magnetic inspection. A similar requirement has been established for some time in the Air Corps Specifications for steel and in the Army-Navy Standard Specifications. A practical interpretation of "aircraft quality" is contained in this requirement.

There is no restriction on the process to be used for magnetic inspection, but up to the present the only process that has proven practicable is magnaflux inspection. Other processes generally require a uniform cross-section and have a much more limited application. Magnaflux inspection will indicate the presence of any non-homogeneity in and just below the surface, whether it be a fatigue crack, grinding crack, seam, lap, or non-metallic inclusion. The process is quite well known and needs no description here; fortunately, also, an authoritative book, "Principles of Magnaflux Inspection" has just been written by F. B. Doane.

In the case of "aircraft quality", magnaflux inspection is most useful for the detection of non-metallic inclusions. It is on this basis that steel is accepted or rejected, yet "aircraft quality" for one part is not necessarily the same as for another part. If the part is made from a forging so that the steel is upset during the fabrication process, the metallurgist may accept a steel with a greater number of magnaflux indications (inclusions) than if the part is machined from the bar without forging — in the former

case the inclusions are often broken up; in the latter case the inclusions in the original material would appear in about the same number and distribution in the finished part.

Since the metallurgist considers inclusions as stress-raisers, another consideration enters into the definition of "aircraft quality", and that is the character and amount of stress in the finished part. For example, "aircraft quality" for piston pins requires a steel practically free from *any* non-metallic inclusions, whereas other parts might require a steel free from inclusions on certain highly-stressed sections, yet tolerate their presence in low-stressed sections. For this reason, the steel manufacturer is generally interested in the parts to be manufactured from "aircraft quality" steels, as it often becomes a matter of selection and allocation to a particular job.

At the present time there is no established standard for the rating of magnaflux indications. This has been recognized and a committee of the Society of Automotive Engineers is now preparing a rating system. This will permit metallurgists to understand each other, but the decision in regard to the rating for each application, and hence the definition of "aircraft quality", will be made on the basis of the requirements for each particular design.

A Classification of Important Composite Steel Products

By Merrill A. Scheil
Research Engineer
and the Metallurgical Research Dept.
A. O. Smith Corp.

FOR SOME TIME, use has been made of composite materials of integrally bonded hard and soft steels of dissimilar composition for heavy duty knives, shear and saw blades, and lathe tools. Such a combination is desirable where a working edge or surface of hard, wear resistant material is required, backed up by a mild steel which incorporates improved shock resistance to the composite tool. The cutting edge may also be a hard non-ferrous alloy or a sintered carbide.

Today, certain types of composite steels are also recognized as important materials of construction for processing equipment used in the chemical, food, paper, and petroleum industries. In such applications equipment must be fabricated from a material having favorable corrosion resisting properties and adequate strength under operating conditions which frequently involve high temperatures. Alloys are available which possess these combined qualities but their cost frequently prohibits their use in solid construction. A composite plate made up of a mild steel base which furnishes the strength to meet design requirements, effectively clad with a moderate thickness of corrosion resistant metal, offers an economical solution. Corrosive conditions encountered in the various industries mentioned above have prompted the use of stainless steel alloys, commercially pure non-ferrous metals, and non-ferrous alloys for claddings on mild steel base.

Steel-backed bearing shells come into this same general classification; the steel for strength and stiffness, the babbitt, bronze or other lining for its anti-friction properties.

A number of processes have been developed to manufacture such composite materials. Each process may be identified by its method of effecting the bond between the two metals. A classification of the commercially important composite metals, with respect to the method of effecting the bond, is listed below. The list makes no pretense to cover the entire field of metals, ferrous and non-ferrous, or all the possibilities of making joints or unions, but is thought to include the important variations of composite steels.

A — Casting On

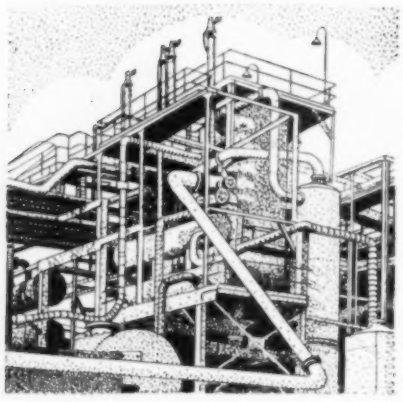
A-1. Composite toolsteel stock is made by casting a high carbon steel around a mild steel ingot prior to rolling, thus effectively bonding a cutting edge or wear resisting surface to the base.
Composite steels — Crucible Steel Co.

A-2. Copper clad stock is made by casting copper around a steel bar. The composite bar is rolled to rod and drawn to wire or a composite ingot rolled to sheet or plate.
Copper Clad wire, rod — Copperweld Steel Co.
Sheet and Plate — Clad Metals Industries
— Republic Steel Corp.

A-3. A stainless clad steel is made by casting mild steel around an assembly of stainless steel plates separated by insulating material and edge welded. The assembly is rolled and separated.
Ingaclad — Ingersoll Steel & Disc Div. of Borg-Warner Corp.

A-4. Steel-backed bearings are made by continuous casting of a layer of babbitt or other bearing metal on a tinned strip of steel, or by centrifugal casting inside a tube.
Continuous — Cleveland Graphite Bronze Co.
Centrifugal — Wilcox-Rich Co. and others

(Continued on page 394)



Chromium Steels
From 2 to 16% Chromium

By H. D. Newell
Chief Metallurgist
The Babcock & Wilcox Tube Co.

USE of the low carbon chromium steels containing between 2% and 16% chromium continues, particularly for oil refining and power generation, where resistance to corrosion or oxidation and tensile properties at elevated temperatures are of primary importance. The oil refining industry has been a particularly large consumer of seamless tubes for stills and piping, and castings for headers, valves and other parts. In steam boiler work when steam temperatures exceed about 900° F. these chromium steels are used for superheater tubes and headers. The commercially important chromium steels for such application usually contain 0.40 to 1.50% molybdenum to assist creep strength and reduce tendency toward embrittlement when cold.

Much time and effort has been expended in developing suitable steel compositions for the variety of service conditions; in consequence, an inordinate number of steels have appeared. In fact, a recent survey showed a total of 38 modifications in the group of tube steels available between plain carbon and 9% chromium. Many of these contained incremental variations of chromium content (in some cases as little as 0.25%), and many were available in high or low silicon content, with aluminum, or with variable molybdenum. This confused engineers attempting to evaluate steels at a given chromium level for maximum economy or appropriateness for a particular set of conditions. Further, it complicated manufacturing and warehousing, especially where small lot orders were received. Many of these steels were interchangeable insofar as service performance of tubes was concerned.

Having been long connected with development of steels of this type, the writer examined manufacturing records to separate the popular steels from the obsolete or little used varieties. It was found that eight or ten steels would adequately cover most of the common applications and, so far as our own company's activities were concerned, the list could be effectively reduced and standardized. Feeling that such a standardization would be of advantage to both consumer and manufacturer, it was discussed with other manufacturers of tubing, after which the tentative list shown as No. 1 to 17 in the table on page 385 was drawn up, to be later re-examined and possibly further reduced in number as conditions warrant. Standardization of the 12% chromium and higher stainless steels for tubing is also in progress, so as to have these analyses conform as closely as tube manufacturing operations will permit to American Iron and Steel Institute code numbers. The proposed list, already adopted by two tube makers, is as given in the lower part of the table.

This effort is parallel to a movement throughout the steel industry, through the auspices of the Iron and Steel Institute, to make up a list of "significant steels". This would not be intended to throttle development of better or cheaper materials but it would require that new steels earn themselves a place on the "significant" list. The list of tube steels given here may be considered a preliminary step in arriving at a list of "significant" wrought tube steels for use in the specialized field of high temperature. It should assist in making selection for a given application easier, facilitate manufacturing procedure and result in eventual reduction in cost and be of general assistance to specification writing bodies. Furthermore, it will expedite deliveries in emergencies when electric steel production is taxed by the defense program.

With regard to specific developments within the recent past, attention may be called to the expanding use of a low alloy, highly creep resistant steel containing 2.25% chromium, 1% molybdenum. This alloy steel is being widely employed for temperature-pressure work where moderate resistance to corrosion suffices. A recently introduced 7% chromium, 0.50% molybdenum, 1% max. silicon steel is supplanting 5% chromium-molybdenum steel in certain oil refinery operations where corrosive stocks are handled; service reports indicate a very

considerable increase in resistance to corrosion for a nominal increase in cost.

Low carbon 12% chromium steel, occasionally with 0.50% molybdenum, continues to be the most widely used lining for pressure vessels. Linings may be attached to the steel shell by a variety of welding methods, either completely bonded or locally attached. In some few instances, 5% chromium-molybdenum (and even 18-8 for the more corrosive conditions) is selected as the liner material. Nozzle liners may be 15 to 16% chromium-iron. Bubble caps and trays may be 5% chromium-molybdenum, 12% chromium or 18-8, depending on the expected severity of corrosion. In steam superheater construction, various chromium-molybdenum steels may be employed. Methods of welding these air hardening steels have been evolved so that composite construction can be had with the higher alloy tubes toward the outlet and the lower alloy toward the inlet side.

Progress in the oil refining industry in polymerization and alkylation of fuel blending agents and aviation gasolines, vapor phase cracking for aromatic compounds, catalytic conversion of hydrocarbons involving periods of reduction and oxidation during conversion and reactivation of the catalyst, and the recent announcements relating to the production of synthetic rubbers are indicative that continued use will be found for these chromium steels both in wrought and cast forms. Perhaps new compositions will ultimately find their way to the "significant" list to satisfy the demands of these new processes. In any event, research and progress will continue unabated in manufacturing and applying these materials to industrial processes.

Simplified List of Electric Furnace Steels for Seamless Tubes for Service at High Temperature

No.	Grade	Carbon	Manganese	Maximum P and S	Silicon	Chromium	Molybdenum	Others
				Carbon Steels, Low and Intermediate Alloy Steels				
1	Carbon steel (Killed, openhearth)	0.10 to 0.20	0.30 to 0.60	*(b)*	0.25	..	..	..
2 *(a)*	C-Mo	0.10 to 0.20	0.30 to 0.60	*(b)*	0.10 to 0.50	..	0.45 to 0.65	..
3 *(a)*	1 Cr, 0.50 Mo	0.15 max.	0.30 to 0.60	0.040	0.30 max.	0.80 to 1.10	0.45 to 0.65	..
4 *(a)*	1.25 Cr, 0.50 Mo, 0.75 Si	0.15 max.	0.30 to 0.60	0.030	0.50 to 1.00	1.00 to 1.50	0.45 to 0.65	..
5	1.75 Cr, 0.70 Mo	0.15 max.	0.40 to 0.60	0.030	0.45 to 0.75	1.50 to 2.00	0.60 to 0.80	..
6	2.00 Cr, 0.50 Mo	0.15 max.	0.30 to 0.60	0.030	0.50 max.	1.75 to 2.25	0.45 to 0.65	..
7	2.25 Cr, 1.00 Mo	0.15 max.	0.30 to 0.60	0.030	0.50 max.	2.00 to 2.50	0.90 to 1.10	..
8	3 Cr, 0.50 Mo, 1.25 Si	0.15 max.	0.50 max.	0.030	1.00 to 1.40	2.75 to 3.25	0.45 to 0.65	..
9	3 Cr, 0.90 Mo	0.15 max.	0.30 to 0.60	0.030	0.50 max.	2.75 to 3.25	0.80 to 1.00	..
10	5 Cr, 0.50 Mo	0.15 max.	0.50 max.	0.030	0.50 max.	4.00 to 6.00	0.45 to 0.65	..
11	5 Cr, 0.50 Mo, 1.5 Si	0.15 max.	0.50 max.	0.030	1.00 to 2.00	4.00 to 6.00	0.45 to 0.65	..
12	5 Cr, 0.50 Mo, 0.45 Ti	0.10 max.	0.50 max.	0.030	0.50 max.	4.00 to 6.00	0.45 to 0.65	Ti, 0.35 to 0.60
13	7 Cr, 0.50 Mo	0.15 max.	0.50 max.	0.030	0.50 to 1.00	6.00 to 8.00	0.45 to 0.65	..
14	7 Cr, 1.00 Mo	0.15 max.	0.50 max.	0.030	0.50 to 1.00	6.00 to 8.00	0.90 to 1.10	..
15	8 Cr, 1.00 Mo	0.15 max.	0.50 max.	0.030	1.00 max.	7.00 to 9.00	0.90 to 1.10	..
16	9 Cr, 1.00 Mo	0.15 max.	0.50 max.	0.030	0.50 to 1.00	8.00 to 10.0	0.90 to 1.10	..
17	9 Cr, 1.35 Mo	0.15 max.	0.50 max.	0.030	0.50 max.	8.00 to 10.0	1.20 to 1.50	..
				High Chromium-Nickel Stainless Steels				
A.I.S.I.							Nickel	
304	18-8	<0.08 *(c)*	2.00 max.	0.025	0.75 max.	18.0 to 20.0	8.0 to 11.0	..
308	20-10	<0.08 *(c)*	2.00 max.	0.025	0.75 max.	19.0 to 22.0	10.0 to 12.0	..
310	25-20	<0.15	2.00 max.	0.025	0.75 max.	24.0 to 26.0	19.0 to 21.0	..
316	16-13-3	<0.10 *(c)*	2.00 max.	0.025	0.75 max.	16.0 to 18.0	11.0 to 14.0	Mo, 2.0 to 3.0
317	18-13-3	<0.10 *(c)*	2.00 max.	0.025	0.75 max.	18.0 to 20.0	11.0 to 14.0	Mo, 3.0 to 4.0
321	18-8-Ti	<0.10 *(c)*	2.00 max.	0.025	0.75 max.	17.0 to 20.0	9.0 to 12.0	Ti = 4 × C, min.
347	18-8-Cb	<0.10 *(c)*	2.00 max.	0.025	0.75 max.	17.0 to 20.0	9.0 to 12.0	Cb = 10 × C, min.
				High Chromium-Iron Stainless Alloys				
410	12	0.15 max.	0.75 max.	0.025	0.75 max.	12.0 to 14.0	0.50 max.	..
418	12-3W	0.15 max.	0.75 max.	0.025	0.75 max.	12.0 to 14.0	0.50 max.	W, 2.0 to 3.5
430	18	0.12 max.	0.75 max.	0.025	0.75 max.	15.0 to 18.0 *(d)*	0.50 max.	..
442	22	0.15 max.	1.00 max.	0.025	0.75 max.	20.0 to 23.0	1.00 max.	..
446	27	0.20 max.	1.50 max.	0.025	0.75 max.	26.0 to 30.0	1.00 max.	..

Notes: *(a)* In either openhearth or electric furnace qualities as specified.
(b) Phosphorus 0.040% max., sulphur 0.045% max.
(c) May also be specified with 0.07% max. carbon.
(d) May be obtained in a restricted range of 15.0 to 16.0% chromium.

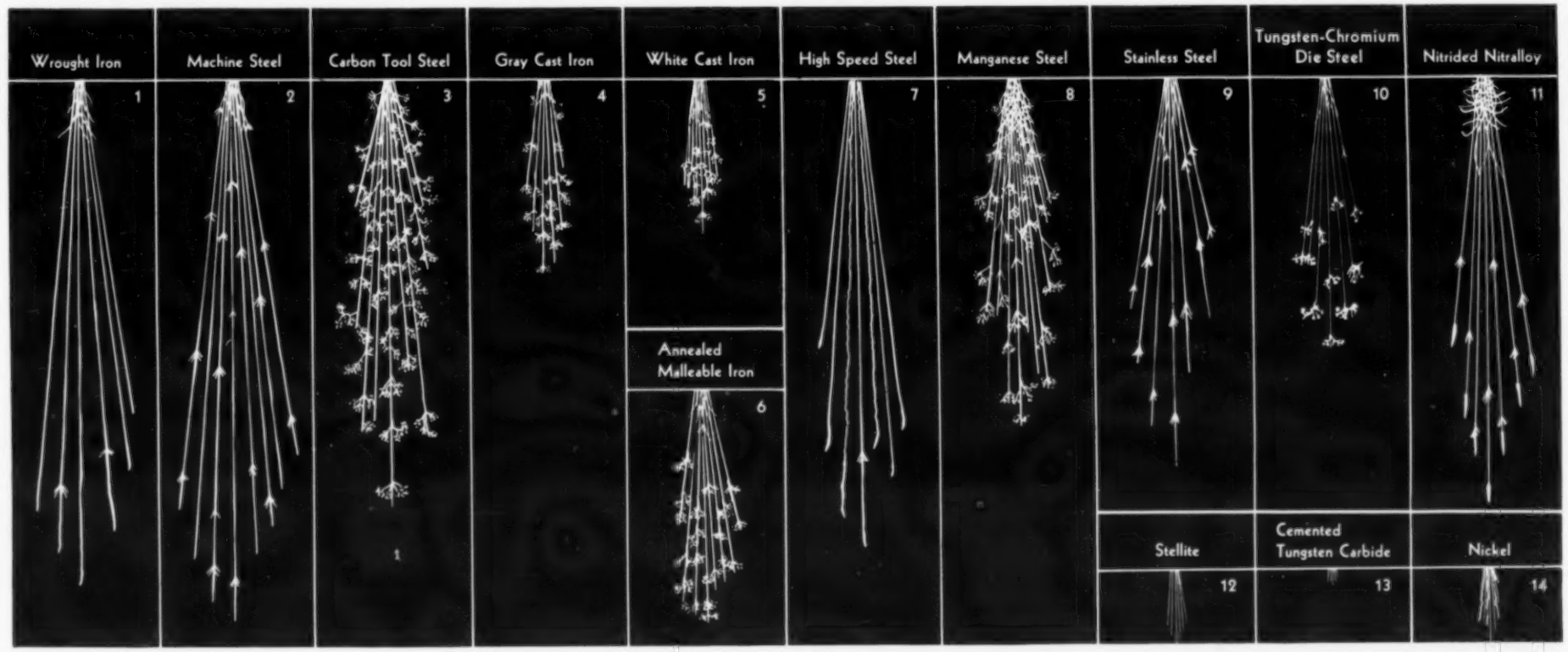
Specific Effects of Alloys in Steel

Element	Solubility		Influence Exerted Through Carbides			Influence on Ferrite	Principal Functions
	In Gamma Iron	In Alpha Iron	Carbide Forming Tendency	Effect on Hardenability	Action During Tempering		
Aluminum Al	1.1% (Increased by C)	30% ±	Less than Fe (Graphitizes)	Mildly positive (If any dissolved in austenite)	.....	Hardens considerably by solid solution	1. Deoxidizes efficiently 2. Restricts grain growth (by forming dispersed oxides or nitrides) 3. Alloying element in nitriding steel
Chromium Cr	12.8% (20% with 0.5% C)	Unlimited	Greater than Mn Less than W	Moderate (Up to 1% more effective than Mn)	Mildly resists softening	Hardens slightly (increases corrosion resistance)	1. Increases corrosion and oxidation resistance 2. Increases hardenability 3. Contributes some strength at high temperatures 4. Resists abrasion and wear (with high carbon)
Cobalt Co	Unlimited	80% ±	Similar to Fe	Negative (That is, decreases it)	Sustains hardness by solid solution	Hardens by solid solution	1. Contributes to red hardness by hardening ferrite
Manganese Mn	Unlimited	15 to 18%	Greater than Fe Less than Cr	Moderate (Ni < Mn < Cr) Retains austenite	Very little, in usual percentages	Hardens markedly and reduces plasticity	1. Counteracts embrittlement by inevitable sulphur 2. Increases hardenability inexpensively 3. Forms batter resistant steel (high Mn, high C)
Molybdenum Mo	3% ± (8% with 0.30% C)	32% (Less with lower temperatures)	Strong Greafer than Cr	Great (When dissolved) Mo > Cr	Opposes softening by a secondary hardening	Gives age hardening systems in high Mo-Fe alloys	1. Raises coarsening temperature of austenite 2. Deepens hardening 3. Raises hot strength, creep resistance and red hardness 4. Enhances corrosion resistance in stainless
Nickel Ni	Unlimited	25% ± (Irrespective of carbon content)	Less than Fe (Graphitizes)	Mild Retains austenite in medium carbon steels	Very little in small percentages	Strengthens and toughens by solid solution	1. Strengthens unquenched or annealed steels 2. Toughens pearlitic-ferritic steels (especially at low temperature) 3. Renders high chromium-iron alloys austenitic
Phosphorus P	0.5%	2.5% (Irrespective of carbon content)	Nil	.....	.....	Effective hardener by solid solution effect	1. Strengthens low carbon steel 2. Increases resistance to corrosion 3. Improves machinability in free-cutting steels
Silicon Si	2% ± (9% with 0.35% C)	18.5% (Even with considerable carbon)	Negative (Graphitizes)	Moderate	Sustains hardness by solid solution	Hardens with loss in plasticity Mn < Si < P	1. Used as general purpose deoxidizer 2. Alloy for electrical and magnetic sheet 3. Improves oxidation resistance 4. Increases hardenability of steels carrying non-graphitizing elements 5. Strengthens low alloy steels
Titanium Ti	0.75% (1% with 0.20% C)	6% ± (Less with lower temperatures)	Maximum (2% Ti renders 0.50% carbon steel unhardenable)	Strong, if dissolved (Persistent carbides restrain grain growth and withhold carbon; therefore reduce hardenability)	Persistent carbides probably unaffected	Age hardening systems in high Ti-Fe alloys	1. Fixes carbon in inert particles (a) Reduces martensitic hardness and hardenability in medium chromium steels (b) Prevents formation of austenite in high chromium steels (c) Prevents localized depletion of chromium in stainless steels during long heating
Tungsten W	6% ± (11% with 0.25% C)	32% (Less with lower temperatures)	Strong	Considerable, especially in small percentages	Opposes softening by secondary hardening	Age hardening systems in high W-Fe alloys	1. Forms hard, abrasion resistant particles in toolsteels 2. Promotes red hardness and hot strength
Vanadium V	1 to 2% (4% with 0.20% C)	Unlimited	Very strong V < Ti or Cb	Marked (When dissolved)	Maximum for secondary hardening	Hardens moderately by solid solution	1. Elevates coarsening temperature of austenite (promotes fine grain) 2. Increases hardenability (when dissolved) 3. Resists tempering 4. Gives marked secondary hardening

Adapted from "The Functions of the Alloying Elements in Steel" by Edgar C. Bain; published by ASM

Spark Test for Metals

Reprinted from "Grits and Grinds" (Norton Co.), June 1940



Line	Metal	Volume of Stream	Length of Stream *(a)*	Color of Stream		Quantity of Spurts *(b)*	Nature of Spurts *(b)*	Line
				Close to Wheel	Near End			
1	Wrought iron	Large	65 in.	Straw	White	Very few	Forked	1
2	Machine steel	Large	70	White	White	Few	Forked	2
3	Carbon toolsteel	Moderately large	55	White	White	Very many	Fine, repeating	3
4	Gray cast iron	Small	25	Red	Straw	Many	Fine, repeating	4
5	White cast iron	Very small	20	Red	Straw	Few	Fine, repeating	5
6	Annealed malleable iron	Moderate	30	Red	Straw	Many	Fine, repeating	6
7	High speed steel	Small	60	Red	Straw	Extremely few	Forked	7
8	Manganese steel	Moderately large	45	White	White	Many	Fine, repeating	8
9	Stainless steel	Moderate	50	Straw	White	Moderate	Forked	9
10	Tungsten-chromium die steel	Small	35	Red	Straw *(c)*	Many	Fine, repeating *(c)*	10
11	Nitrided nitralloy	Large (curved)	55	White	White	Moderate	Forked	11
12	Stellite	Very small	10	Orange	Orange	None		12
13	Cemented tungsten carbide	Extremely small	2	Light orange	Light orange	None		13
14	Nickel	Very small *(d)*	10	Orange	Orange	None		14
15	Copper, brass, aluminum	None				None		15

(a) Figures obtained with 12-in. wheel on bench stand, and are relative only. Actual length in each instance will vary with grinding wheel and pressure.

(b) "Spurts" are the sparks (seemingly small explosions) that occur at intervals on the carrier lines.

(c) Spurts are blue-white.

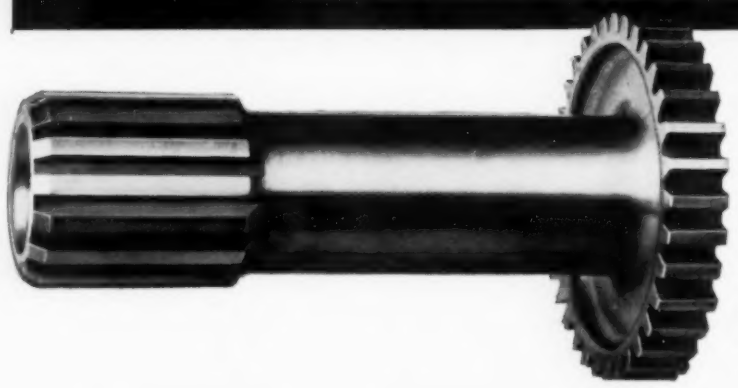
(d) Some wavy streaks may be observed.

Adding NICKEL TO GEAR STEELS

1—IMPROVES *mechanical properties*
2—SIMPLIFIES *fabricating problems*

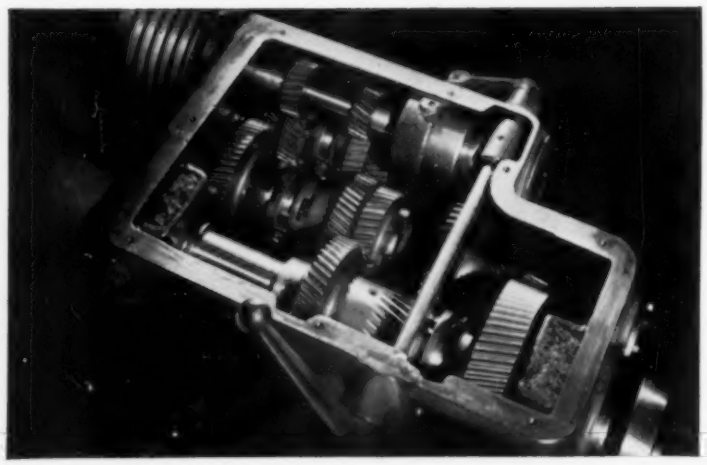
PERMISSIBLE COMPRESSIVE STRESSES ON ENGAGED GEAR TEETH		
TYPE	NICKEL ALLOY STEELS S.A.E. Classification	PERMISSIBLE COMPRESSIVE STRESS*
Direct Hardening	3150, 4640, 4650, etc.	170,000 lb./sq. in.
Carburizing	3115, 3120	180,000 lb./sq. in.
Carburizing	2315, 2320, 4615, 4620	200,000 lb./sq. in.
Carburizing	3312, 4815, 4820, 2515	215,000 lb./sq. in.

*Compressive stresses calculated from Hertz formula. These values are for intermittently loaded gears and should be reduced 20/25% for constant mesh loading.



Choosing the most suitable gear steel depends upon getting mechanical properties to safely meet service requirements. But of equal importance are fabricating properties ...uniform response to heat treatment with minimum distortion and freedom from cracking, plus *economical machining*. Today's higher speeds and heavier tooth loadings emphasize the advantages of specifying direct hardening and carburizing gear steels alloyed with Nickel...Nickel alone or in combination.

Hollow quill shaft with integral gear and splines, pictured at left, must be resilient to absorb torque of 500 HP Ranger aircraft engine. To maintain tooth contours and resist fatigue stresses this vital shaft is forged from 3½% Nickel, 1½% chromium steel, SAE 3340.



Strong, tough and wear-resistant, headstock gears in Monarch lathes are 3½% Nickel steel, SAE 2350.

JUST PUBLISHED

"Modern Trends in Nickel Steel and Cast Iron Gear Materials," a paper presented before the American Gear Manufacturers Association 22nd semi-annual meeting. For your copy of this 16-page illustrated booklet, or for personal answers to your gear problems, please address:

THE INTERNATIONAL NICKEL COMPANY, INC. **67 WALL STREET NEW YORK, N. Y.**

Nickel Steels and Irons

By John W. Sands
Development and Research Dept.
International Nickel Co.

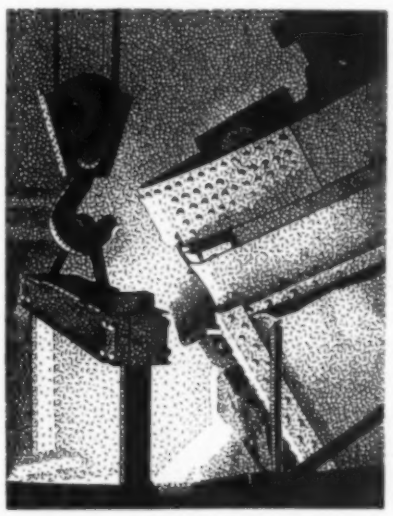
WITH PRODUCTION being stepped up throughout industry, the strong trend towards the wider uses of existing alloys and the development of new materials, so evident in the past decade and a half, is now gaining tremendous strength. All alloys — ferrous and non-ferrous — are involved.

For instance, the nickel-copper alloy steels, recently developed commercially and sponsored as proprietary products by many steel makers, are rapidly extending their markets in the transportation field, and are finding an extensive use for drill pipe and other applications in the petroleum industry. They have better fatigue properties and improved corrosion resistance than the materials they are replacing. Excellent welding qualities are a factor augmenting the use of low carbon nickel alloy steels, particularly for low temperature service in petroleum refining and domestic gas generating and handling equipment.

There is also an increased interest in the higher alloyed steels containing as much as 3½ to 5% nickel, interest especially shown in the chemical and process industries. A case in point is the large quantities of 5% nickel steel tubing which have been installed in black liquor evaporators in paper mills.

Pronounced activity in the aircraft industry is bringing about increased use of the high strength, low alloy, heat treated steels for their structural parts. These include tubing for engine mounts and landing gears, propeller blades, shafts and hubs, blade nuts, bolts, gears, and connecting rods.

Automotive and aviation production is adopting more nickel-chromium-molybdenum steel for stressed parts to be intricately machined after heat treatment to 450 Brinell, once considered impractical. This is receiving increased attention from industry and has served to simplify heat treating and machining practice by eliminating distortion as a factor to be considered and by generally improving dimensional accuracy of the finished parts. Applications so far have been largely confined to S.A.E. 4340 nickel-chromium-molybdenum steel and include truck axle shafts, aircraft gears, propellers and spiders, crankshafts, undercarriage parts, and engine-mount fittings.



Alloy cast irons — With more than 10 years' experience behind them in the production of alloyed cast irons, foundrymen have made marked progress in large volume production.

Increased knowledge and improved technique in the production of these irons have enabled them not only to develop high standards of quality, but have also to meet increasingly rigid specifications. Thus, the manufacturer of high quality equipment is able to depend on thoroughly reliable suppliers. The builders of machine tools are outstanding examples; with a heavy demand for their products they are still able to deliver high quality without being delayed by lack of information or experience in the handling of complex alloyed cast irons.

For large forming dies, the aircraft industry has adopted the same specifications of nickel-chromium irons utilized for automobile bodies.

Titanium in Steel and Iron

By George F. Comstock
Metallurgist, The Titanium Alloy Manufacturing Co.

THE DEVELOPMENT which has aroused the greatest interest in titanium, as applied to steel production, during the past year, is probably the announcement of the "Grainal" alloys — complex deoxidizers containing aluminum, titanium, and generally a hardening agent such as vanadium. The titanium is found to protect and intensify the hardening effect of the more expensive vanadium in these alloys, so that smaller additions of that element are effective.

With the characteristics of a fine-grained metal imparted by deoxidation with aluminum and titanium, steels treated in this way are found to have a specially desirable combination of strength and ductility, together with hardness, when quenched and drawn. This treatment is chiefly applied to the forging steels containing about 0.40% carbon and 1.80% manganese [as is noted in the article by Mr. Roush on page 379 of this issue].

Analyses of S.A.E. Steels

Numerical designations and analyses approved as standard by Society of Automotive Engineers

Carbon Steels

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.
1010	0.05-0.15	0.30-0.60	0.045	0.055
1015	0.10-0.20	0.30-0.60	0.045	0.055
X1015	0.10-0.20	0.70-1.00	0.045	0.055
1020	0.15-0.25	0.30-0.60	0.045	0.055
X1020	0.15-0.25	0.70-1.00	0.045	0.055
1025	0.20-0.30	0.30-0.60	0.045	0.055
X1025	0.20-0.30	0.70-1.00	0.045	0.055
1030	0.25-0.35	0.60-0.90	0.045	0.055
1035	0.30-0.40	0.60-0.90	0.045	0.055
1040	0.35-0.45	0.60-0.90	0.045	0.055
X1040	0.35-0.45	0.40-0.70	0.045	0.055
1045	0.40-0.50	0.60-0.90	0.045	0.055
X1045	0.40-0.50	0.40-0.70	0.045	0.055
1050	0.45-0.55	0.60-0.90	0.045	0.055
X1050	0.45-0.55	0.40-0.70	0.045	0.055
1055	0.50-0.60	0.60-0.90	0.040	0.055
X1055	0.50-0.60	0.90-1.20	0.040	0.055
1060	0.55-0.70	0.60-0.90	0.040	0.055
1065	0.60-0.75	0.60-0.90	0.040	0.055
X1065	0.60-0.75	0.90-1.20	0.040	0.055
1070	0.65-0.80	0.60-0.90	0.040	0.055
1075	0.70-0.85	0.60-0.90	0.040	0.055
1080	0.75-0.90	0.60-0.90	0.040	0.055
1085	0.80-0.95	0.60-0.90	0.040	0.055
1090	0.85-1.00	0.60-0.90	0.040	0.055
1095	0.90-1.05	0.25-0.50	0.040	0.055

Free Cutting Steels

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Range	Sulphur Range
1112	0.08-0.16	0.60-0.90	0.09-0.13	0.10 -0.20
X1112	0.08-0.16	0.60-0.90	0.09-0.13	0.20 -0.30
1115	0.10-0.20	0.70-1.00	0.045 max.	0.075-0.15
1120*	0.15-0.25	0.60-0.90	0.045 max.	0.075-0.15
X1314	0.10-0.20	1.00-1.30	0.045 max.	0.075-0.15
X1315	0.10-0.20	1.30-1.60	0.045 max.	0.075-0.15
X1330	0.25-0.35	1.35-1.65	0.045 max.	0.075-0.15
X1335	0.30-0.40	1.35-1.65	0.045 max.	0.075-0.15
X1340	0.35-0.45	1.35-1.65	0.045 max.	0.075-0.15

*Practically superseded by S.A.E. 1115

Manganese Steels

See Note (a) for Silicon Content

No.	Carbon	Manganese	Phosphorus	Sulphur
T1330	0.25-0.35	1.60-1.90	0.040 max.	0.050 max.
T1335	0.30-0.40	1.60-1.90	0.040 max.	0.050 max.
T1340	0.35-0.45	1.60-1.90	0.040 max.	0.050 max.
T1345	0.40-0.50	1.60-1.90	0.040 max.	0.050 max.
T1350	0.45-0.55	1.60-1.90	0.040 max.	0.050 max.

Nickel Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Nickel
2015	0.10-0.20	0.30-0.60	0.40-0.60
2115	0.10-0.20	0.30-0.60	1.25-1.75
2315	0.10-0.20	0.30-0.60	3.25-3.75
2320	0.15-0.25	0.30-0.60	3.25-3.75
2330	0.25-0.35	0.50-0.80	3.25-3.75
2335	0.30-0.40	0.50-0.80	3.25-3.75
2340	0.35-0.45	0.60-0.90	3.25-3.75
2345	0.40-0.50	0.60-0.90	3.25-3.75
2350	0.45-0.55	0.60-0.90	3.25-3.75
2515	0.10-0.20	0.30-0.60	4.75-5.25

Molybdenum Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

S.A.E. No.	Carbon	Manganese	Chromium	Nickel	Molybdenum
4130	0.25-0.35	0.50-0.80	0.50-0.80	.....	0.15-0.25
X4130	0.25-0.35	0.40-0.60	0.80-1.10	.....	0.15-0.25
4135	0.30-0.40	0.60-0.90	0.80-1.10	.....	0.15-0.25
4140	0.35-0.45	0.60-0.90	0.80-1.10	.....	0.15-0.25
4150	0.45-0.55	0.60-0.90	0.80-1.10	.....	0.15-0.25
4320	0.15-0.25	0.40-0.70	0.30-0.60	1.65-2.00	0.20-0.30
4340	0.35-0.45	0.50-0.80	0.50-0.80	1.50-2.00	0.30-0.40
X4340	0.35-0.45	0.50-0.80	0.60-0.90	1.50-2.00	0.20-0.30
4615	0.10-0.20	0.40-0.70	.....	1.65-2.00	0.20-0.30
4620	0.15-0.25	0.40-0.70	.....	1.65-2.00	0.20-0.30
4640	0.35-0.45	0.50-0.80	.....	1.65-2.00	0.20-0.30
4815	0.10-0.20	0.40-0.60	.....	3.25-3.75	0.20-0.30
4820	0.15-0.25	0.40-0.60	.....	3.25-3.75	0.20-0.30

Chromium Steels

See Note (a) for Silicon Content

S.A.E. No.	Carbon Range	Manganese Range	Phosphorus Max.	Sulphur Max.	Chromium Range
5120	0.15-0.25	0.30-0.60	0.040	0.050	0.60-0.90
5140	0.35-0.45	0.60-0.90	0.040	0.050	0.80-1.10
5150	0.45-0.55	0.60-0.90	0.040	0.050	0.80-1.10
52100	0.95-1.10	0.20-0.50	0.030	0.035	1.20-1.50

Nickel-Chromium Steels

See Notes (a) and (b) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Nickel	Chromium
3115	0.10-0.20	0.30-0.60	1.00-1.50	0.45-0.75
3120	0.15-0.25	0.30-0.60	1.00-1.50	0.45-0.75
3125	0.20-0.30	0.50-0.80	1.00-1.50	0.45-0.75
3130	0.25-0.35	0.50-0.80	1.00-1.50	0.45-0.75
3135	0.30-0.40	0.50-0.80	1.00-1.50	0.45-0.75
3140	0.35-0.45	0.60-0.90	1.00-1.50	0.45-0.75
X3140	0.35-0.45	0.60-0.90	1.00-1.50	0.60-0.90
3145	0.40-0.50	0.60-0.90	1.00-1.50	0.45-0.75
3150	0.45-0.55	0.60-0.90	1.00-1.50	0.45-0.75
3215	0.10-0.20	0.30-0.60	1.50-2.00	0.90-1.25
3220	0.15-0.25	0.30-0.60	1.50-2.00	0.90-1.25
3230	0.25-0.35	0.30-0.60	1.50-2.00	0.90-1.25
3240	0.35-0.45	0.30-0.60	1.50-2.00	0.90-1.25
3245	0.40-0.50	0.30-0.60	1.50-2.00	0.90-1.25
3250	0.45-0.55	0.30-0.60	1.50-2.00	0.90-1.25
3312	max. 0.17	0.30-0.60	3.25-3.75	1.25-1.75
3325	0.20-0.30	0.30-0.60	3.25-3.75	1.25-1.75
3335	0.30-0.40	0.30-0.60	3.25-3.75	1.25-1.75
3340	0.35-0.45	0.30-0.60	3.25-3.75	1.25-1.75
3415	0.10-0.20	0.30-0.60	2.75-3.25	0.60-0.95
3435	0.30-0.40	0.30-0.60	2.75-3.25	0.60-0.95
3450	0.45-0.55	0.30-0.60	2.75-3.25	0.60-0.95

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Caution: Check with S.A.E. for possible modifications before making important commitments

Chromium-Vanadium Steels

See Notes (a) and (c) for Silicon, Phosphorus and Sulphur

S.A.E. No.	Carbon Range	Manganese Range	Chromium Range	—Vanadium— Minimum	Desired
6115	0.10-0.20	0.30-0.60	0.80-1.10	0.15	0.18
6120	0.15-0.25	0.30-0.60	0.80-1.10	0.15	0.18
6125	0.20-0.30	0.60-0.90	0.80-1.10	0.15	0.18
6130	0.25-0.35	0.60-0.90	0.80-1.10	0.15	0.18
6135	0.30-0.40	0.60-0.90	0.80-1.10	0.15	0.18
6140	0.35-0.45	0.60-0.90	0.80-1.10	0.15	0.18
6145	0.40-0.50	0.60-0.90	0.80-1.10	0.15	0.18
6150	0.45-0.55	0.60-0.90	0.80-1.10	0.15	0.18
6195(c)	0.90-1.05	0.20-0.45	0.80-1.10	0.15	0.18

Tungsten Steels

See Notes (a) and (d) for Silicon, Phosphorus and Sulphur

No.	Carbon	Manganese	Chromium	Tungsten
71360	0.50-0.70	0.30 max.	3.00-4.00	12.00-15.00
71660	0.50-0.70	0.30 max.	3.00-4.00	15.00-18.00
7260	0.50-0.70	0.30 max.	0.50-1.00	1.50- 2.00

Silicon-Manganese Steels

See Note (b) for Phosphorus and Sulphur

No.	Carbon	Manganese	Silicon
9255	0.50-0.60	0.60-0.90	1.80-2.20
9260	0.55-0.65	0.60-0.90	1.80-2.20

Corrosion and Heat Resisting Alloys

See Note (e) for Silicon, Phosphorus and Sulphur Content

No.	Carbon	Manganese	Chromium	Nickel
30905	0.08 max.	0.20-0.70	17.00-20.00	8.00-10.00
30915	0.09-0.20	0.20-0.70	17.00-20.00	8.00-10.00
51210	0.12 max.	0.60 max.	11.50-13.00	.....
X51410	0.12 max.	0.60 max.	13.00-15.00	.....
51335	0.25-0.40	0.60 max.	12.00-14.00	.....
51510	0.12 max.	0.60 max.	14.00-16.00	.....
51710	0.12 max.	0.60 max.	16.00-18.00	.....

Notes to Tables of Chemical Composition

Note (a). Silicon range of all S.A.E. basic openhearth alloy steels shall be 0.15 to 0.30%. For electric furnace alloy steels and acid openhearth alloy steels, the silicon content shall be 0.15% minimum.

Note (b). Phosphorus and sulphur in all S.A.E. nickel steels, nickel-chromium steels, molybdenum steels and silicon-manganese steels shall be 0.040% max. and 0.050% max. respectively.

Note (c). Phosphorus in all S.A.E. chromium-vanadium steels shall be 0.040% max. except in No. 6195, which shall be 0.030% max. Sulphur in all S.A.E. chromium-vanadium steels shall be 0.050% max. except in No. 6195, which shall be 0.035% max.

Note (d). Phosphorus and sulphur in all S.A.E. tungsten steels shall be 0.035% and 0.040% max. respectively.

Note (e). Silicon shall be 0.50% max. except in alloys 30905 and 30915, which may be 0.75% max. Phosphorus shall be 0.030% max. in all corrosion and heat resisting alloys. Sulphur shall be 0.030% max. in all except in the free cutting alloy X51410, which shall be in the range 0.15 to 0.50%.

In steel castings the use of about 5 lb. of high carbon ferrotitanium per ton continues to be fairly general practice in the intermediate manganese grade, this treatment having been found to give a better combination of strength, ductility, and impact value than either stronger or weaker deoxidation in that grade of steel.

The largest use of titanium in steel continues to be the treatment of rimming steel in the ladle with small additions of the high or medium carbon alloy, for improving the rimming action in the molds so as to produce thick-skinned ingots that roll better without cracking. Ferro-carbon-titanium continues to be used widely in killed steels also, for such purposes as to secure better distribution of sulphides, greater uniformity and cleanness in fine-grained steels, and less chipping cost due to seams.

In heat resisting steels, especially the highly alloyed cast grades, final deoxidation with a high-grade low carbon, low aluminum ferro-titanium is becoming a more general practice, not only for thorough degasification and scavenging, but also for refining the dendritic crystallization structure. In the 4 to 6% chromium steels, which are so widely used for heat resisting tubes, the advantages of a titanium content have recently been more clearly described by HABART in April METAL PROGRESS. These include not only the reduction or elimination of air hardening on rapid cooling, but also marked improvements in long-time resistance to scale loss and pitting at 1600 to 1650° F., and in impact value after annealing.

In lower chromium steels that are so popular for thin-walled airplane tubing, the advantages of small titanium contents for improving weldability have been reported by the present writer in *Metals and Alloys* for July. It is also interesting to note the expanding use of various titanium alloys, such as manganese-titanium and nickel-titanium, in powder form as ingredients of welding rod coatings, for deoxidation, cleaning, and grain refining the metal in fusion welds of steel.

An interesting new development in the use of titanium in cast iron is the discovery by JOMINY of its value, in somewhat more than the usual percentages, for improving the wear resistance of cylinder liners in internal combustion engines. This has been the subject of two recent patents. The chief commercial use of titanium in cast iron continues at present, however, to be for deoxidation, grain refinement, and graphitizing—the high carbon ferrotitanium being most used in electric melted cast iron, and a low carbon, ferro-silicon-titanium for iron melted in cupolas.

Vanadium in Steel

By Jerome Strauss
Vice-President
Vanadium Corp. of America

VERY BROADLY, vanadium serves industry in two groups of ferrous metallurgical products — toolsteels and constructional steels, using "constructional" in a broad sense to include the construction of machinery and equipment of all sorts.

In the former, no strikingly new products or processes have appeared during the past year, but significant progress has been made in the fabrication and use of the high speed steels of higher vanadium content. As has been pointed out by many writers, there has been a constant trend in the vanadium content of high speed toolsteels from the 0.25% of 30 or more years ago, to the present 1¼% of the so-called 18-4-1 standard steel and the 2 to 4% of the modern heavy duty steels. Only recently, however, has there been full appreciation of the need of a considerably higher carbon in the latter so as to use the vanadium most effectively in producing maximum cutting capacity. This entailed originally some fabricating difficulties, but as these are being ironed out, wider and wider use is being made of the new compositions, utilizing to the fullest extent the capacity of modern machine tools.

The effectiveness of very small amounts of vanadium in constructional steels subjected to the most severe service (and the influence of such small additions toward regularity of performance, ton after ton and heat after heat, which still accounts for the widespread use of chromium-vanadium spring steel in railway,

Toolsteels Classified by Wear-Toughness Ratio

By Harold B. Chambers (See Metal Progress, June 1940, for Its Use as a Tool Selector)

Each of the three groups arranged in order of increasing toughness and decreasing wear resistance. Figures indicated as max. are optional and may be present up to amount noted. Since the difference in relative wear-toughness capacities of adjacent classes is small to negligible, the many brands covered by each class may be expected to give competitive performance except when highly standardized operating conditions require that consideration be given to the footnotes.

Class	Conventional Type Names	Carbon	Manganese	Silicon	Tungsten	Chromium	Vanadium	Molybdenum	Cobalt	Nickel	Notes
	Water Hardening Steels										
1A	Tungsten finishing	1.25-1.50	0.15-0.35	0.15-0.50	2.50- 6.00	1.80 max.	0.30 max.	0.50 max.			A,B,C
1B	Carbon or carbon-vanadium	1.30-1.45	0.15-0.35	0.15-0.35		0.35 max.	0.30 max.				A,C
2A	High carbon, low tungsten	1.10-1.30	0.15-0.35	0.15-0.35	1.00- 2.50	0.35 max.	0.30 max.				A,B
2B	Low chromium or chrome-vanadium	1.10-1.30	0.15-0.35	0.15-0.35		0.10- 1.20	0.30 max.				A,C
2C	Carbon or carbon-vanadium	1.10-1.30	0.15-0.35	0.15-0.35			0.30 max.				A
3A	High carbon, low tungsten	0.90-1.10	0.15-0.35	0.15-0.35	1.00- 2.50	0.75 max.	0.30 max.				A,B,C
3B	Low chromium or chrome-vanadium	0.90-1.10	0.15-0.35	0.15-0.35		0.10- 1.50	0.30 max.				A,C
3C	Carbon or carbon-vanadium	0.90-1.10	0.15-0.35	0.15-0.50			0.50 max.				A,D
4A	Chrome-molybdenum or chrome-vanadium	0.55-0.90	0.15-0.35	0.15-0.35		0.40- 1.20	0.35 max.	0.25 max.		0.50 max.	A,C
4B	Carbon or carbon-vanadium	0.70-0.90	0.15-0.35	0.15-0.35			0.30 max.				A
4C	Silico-manganese or silico-molybdenum	0.45-0.75	0.35-1.00	0.75-2.25		0.60 max.	0.35 max.	0.60 max.			A,E
	Oil Hardening and Air Hardening Steels (Tools of Intricate Design)										
5A	High carbon, high chromium	1.80-2.50	0.15-1.20	0.15-1.00	2.00 max.	10.50-14.00	1.25 max.	0.30 max.	1.00 max.	1.00 max.	A,F,G
5B	High carbon, high chromium	1.80-2.40	0.15-0.60	0.15-0.50		10.50-14.00	1.20 max.	0.70- 1.00	0.60 max.		A,F,G
5C	High carbon, high chromium	1.30-1.70	0.15-0.60	0.15-0.50		10.50-14.00	1.20 max.	0.50- 1.25	4.00 max.	1.00 max.	A,F,G
5D	High carbon, high chromium	0.90-1.30	0.15-1.20	0.15-1.00		4.50-13.00	0.75 max.	0.70- 1.25	0.60 max.		A,F,G
6A	Chrome-molybdenum	1.10-1.30	0.35-0.95	0.15-0.35		0.40- 1.75		0.25- 0.75			A,E
6B	High carbon, low tungsten	1.10-1.30	0.15-0.70	0.15-0.35	1.00- 2.50	0.35- 1.25	0.30 max.				A,B,C
6C	Low chromium or chrome-vanadium	1.10-1.30	0.35-0.70	0.15-0.35		0.40- 1.50	0.30 max.				A,C
7A	Chromium non-deforming	0.90-1.10	0.35-1.10	0.15-0.50	1.10 max.	0.90- 1.60	0.30 max.	0.50 max.			A,E
7B	Manganese non-deforming	0.80-1.10	0.85-1.80	0.15-0.50	0.70 max.	0.90 max.	0.30 max.	0.35 max.			A,E
8A	Low tungsten-chromium	0.40-0.65	0.15-0.35	0.15-1.50	0.75- 3.00	0.50- 2.00	0.50 max.	0.35 max.			A,E
8B	Chrome-nickel or chrome-nickel-molybdenum	0.50-0.80	0.35-0.90	0.15-0.35		0.50- 1.25	0.30 max.	0.80 max.		1.00-2.50	A,E
8C	Chrome-molybdenum, chrome-vanadium, or manganese-molybdenum	0.50-0.90	0.35-0.90	0.15-0.50		1.20 max.	0.35 max.	0.40 max.		0.50 max.	A,E
8D	Silico-molybdenum	0.45-0.60	0.35-1.25	0.75-2.25	0.20 max.	0.75 max.	0.60 max.	0.15- 2.00			A,E
	High Speed (H.S.) Steels and Hot Work (H.W.) Steels (Tools Which Heat Up)										
9A	Tungsten-cobalt high speed	0.70-0.90	0.15-0.35	0.15-0.35	18.00-23.00	3.50- 4.75	1.25-2.50	1.25 max.	9.00-15.00		A,G,H
9B	Tungsten-cobalt high speed	0.65-0.90	0.15-0.35	0.15-0.35	17.00-21.00	3.50- 4.75	1.25-2.50	1.25 max.	5.00- 9.00		A,G,H
9C	Molybdenum-cobalt H.S.	0.75-0.90	0.15-0.35	0.15-0.35	2.00 max.	3.50- 4.75	1.25-2.50	7.00-10.00	3.00- 8.00		A,G,H
9D	Tungsten-cobalt high speed	0.65-0.80	0.15-0.35	0.15-0.35	17.00-20.00	3.50- 4.75	0.75-1.50	1.00 max.	2.00- 5.00		A,G,H
9E	Tungsten-cobalt high speed	0.65-0.85	0.15-0.35	0.15-0.35	12.00-15.00	3.50- 4.75	1.50-2.25	0.75 max.	3.00- 8.00		A,G,H
10A	18-4-4 and 18-4-3 high speed	0.90-1.30	0.15-0.35	0.15-0.50	17.00-19.00	3.50- 4.75	2.50-4.00	1.00 max.			A,H
10B	18-4-2 high speed	0.75-0.90	0.15-0.35	0.15-0.50	17.00-19.00	3.50- 4.75	1.50-2.50	1.00 max.			A,H
10C	18-4-1 high speed	0.55-0.80	0.15-0.35	0.15-0.75	16.00-21.00	3.50- 4.75	0.50-1.50				A,H
10D	Molybdenum-tungsten H.S.*	0.70-1.30	0.15-0.35	0.15-0.35	5.00- 6.50	3.50- 4.75	1.25-4.00	4.00- 6.50			A,H
10E	Molybdenum-vanadium H.S.*	0.70-1.30	0.15-0.35	0.15-0.35		3.50- 4.75	1.50-4.00	7.00- 9.00			A,H
10F	Molybdenum-tungsten H.S.	0.65-0.85	0.15-0.35	0.15-0.35	1.00- 2.50	3.50- 4.75	0.75-1.50	6.00- 9.50			A,H
10G	14-4-2 and 14-4-1 high speed	0.55-0.80	0.15-0.35	0.15-0.35	13.00-15.00	3.50- 4.75	0.75-2.25				A,H
11A	Low carbon high speed	0.45-0.60	0.15-0.35	0.15-0.35	16.00-19.00	3.00- 4.50	0.50-1.25				A,H,I
11B	High tungsten hot work	0.25-0.60	0.15-0.35	0.15-0.35	12.00-16.00	2.50- 4.50	0.30-0.60				A,H,I
11C	Tungsten hot work	0.25-0.50	0.15-0.35	0.15-0.35	8.00-12.00	1.25- 3.50	0.60 max.	0.30 max.		2.25 max.	A,H,I
11D	Tungsten-chromium H.W.	0.30-0.60	0.15-0.75	0.35-1.50	4.00- 7.50	4.50- 7.50	0.60 max.	0.50 max.	0.60 max.	0.50 max.	A,H,I
12A	Low tungsten-chromium H.W.	0.40-0.65	0.15-0.35	0.15-1.00	1.50- 3.00	0.75- 2.00	0.50 max.	0.35 max.			A,H
12B	Chrome-molybdenum H.W.	0.30-0.50	0.15-1.25	0.80-1.10	1.25 max.	4.00- 7.50	0.50 max.	0.45- 1.75	0.60 max.	1.75 max.	A,H
12C	Chrome-molybdenum H.W. or chromium hot work	0.40-1.00	0.15-0.75	0.15-0.75		2.25- 4.50	1.00 max.	0.80 max.			A,H
12D	Chrome-nickel hot work or chrome-nickel-molybdenum hot work	0.30-0.60	0.35-0.80	0.15-0.35		0.50- 2.50	0.30 max.	1.00 max.		1.25-5.00	A,H

A. Wear resistance increases and toughness decreases as carbon content increases.

B. Wear resistance increases and toughness decreases as tungsten content increases.

C. Hardenability increases, wear resistance increases, toughness decreases, movement in hardening decreases, and tendency for soft spots in hardening decreases as chromium content increases.

D. Some special applications (silverware striking dies, certain header dies, etc.) may occasionally require extra penetration of hardness, which may be produced by adjusting manganese and silicon contents.

E. Hardenability increases, wear resistance increases and toughness decreases as total alloy content increases.

F. Machining difficulties increase as total alloy content increases.

G. Red hardness properties increase and toughness decreases as cobalt content increases.

H. Red hardness properties increase and toughness decreases as total alloy content increases.

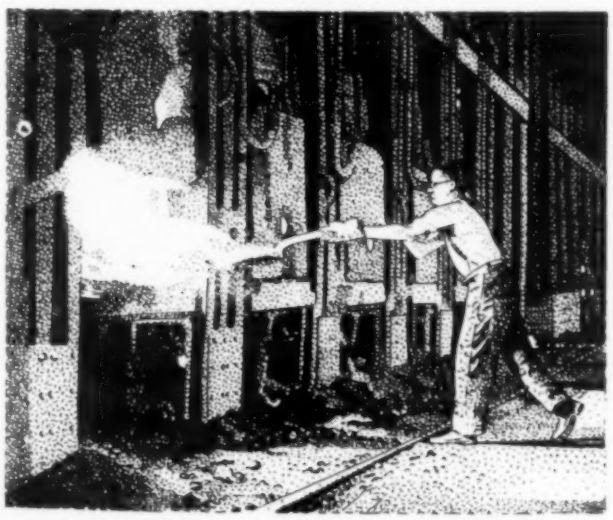
I. Water cooling surface in operation, particularly when intermittent, tends to promote heat checking approximately in proportion to tungsten content.

*Relative position based on lower carbon ranges only.

bus, and truck operation) has now been felt in many items of ordnance. Vanadium is likewise almost an universal constituent of heavy forgings of high strength, such as turbine shafts and the like, because its benefits show up so regularly in high transverse ductility.

In discussing regularity of properties and performance, one should refer back to the Review Number of METAL PROGRESS of October 1939 in which JOHN CHIPMAN in his most readable contribution on "Refining Methods" refers to progress in "research on the basic principles underlying steel making methods and in making available to the steel maker new information, new aids in the control of his process, new kinds of equipment which will enable him to do a better job." Among these "aids" mention may be made of the group of steel-making alloys announced during the past year under the generic name of "Grainal", primarily vanadium-titanium-aluminum ferro-alloys, which serve not only to increase the hardening capacity of ferritic constructional steels of a given chemical composition, but also to reduce the variability in successive heats of a given composition.

This property of hardenability (now known to be one of the vital distinguishing characteristics that makes its presence known in the much-discussed differences between heats of like ordinary chemical composition in respect to their reaction to thermal treatment, mechanical working and other forms of fabrication) may now be subjected to more effective use. The application of these alloys to steel making has done much to point a way to Dr. CHIPMAN's "narrower groove of smaller deviations", in addition to making steels capable of full hardening in somewhat heavier sections and imparting to them greatly increased ductility in the quenched and tempered condition, especially at high hardnesses. They are just one more step toward improved productivity.



Molybdenum Steels and Irons

By Alvin J. Herzig
Chief Metallurgist
Climax Molybdenum Co. of Michigan

A SUMMARY of recent metallurgical developments involving molybdenum steels and irons, even if discussion is confined to interesting happenings and to new alloys and expanding uses of molybdenum as they touch upon iron and steel production, would be an extended article. Alloying elements like molybdenum may express their presence, either directly or indirectly, in the engineering properties attainable by the selection of a proper steel composition and heat treatment. Such alloying elements may also be as important if they are regarded solely from the standpoint of their influence on mill, foundry and shop operations and product design.

For the purpose of this discussion, a brief review of some developments observed during the past year that may have a bearing on present and future applications for molybdenum steel and molybdenum cast iron will be given. While discussion or even mention here should not be interpreted as necessarily establishing a definite trend, the following new or extended applications appear to have more than passing significance:

As might be expected, the airplane industry has seen some striking metallurgical advances during the year, many of which involve the use of molybdenum. The established use of S.A.E. X-4130 for structural parts has been extended, and at least one producer is using a composition which would correspond to S.A.E. 4330 for propellers. Another manufacturer reports the development of a satisfactory welding technique and is specifying S.A.E. 4340 tubing for engine mounts; high tensile and fatigue strength are available in this steel.

Three new airplane steels containing molybdenum have entered the field since a year ago. A 3% chromium steel with molybdenum can be nitrided and shows minimum sensitivity to mass effect; this was introduced from England and has been successfully used for crankshafts. Another nitriding steel containing chromium, molybdenum and nickel (but no aluminum) is also being specified by aircraft producers. In addition, a steel containing 2% chromium with 0.50% molybdenum has been used with success for cylinder liners for aircraft engines.

The extensive modernization and locomotive rebalancing programs undertaken by American railroads have had an appreciable influence on the demand for molybdenum steels. The use of nickel-chromium-molybdenum rods, pistons, axles, shafts and pins to reduce fatigue failures and save weight is now widely established. Carbon-molybdenum boiler steel is being tested to permit higher boiler pressures without requiring increased weight; service has been encouraging. Other growing applications for molybdenum steels and cast irons by American railroads include tires, car wheels, flues and cylinders.

The past "model-year" saw production schedules of the motor industry set for about 4,200,000 vehicles. Nickel-molybdenum carburizing steel (S.A.E. 4615 and 4620) continues as perhaps the most widely used specification for gears. Other typical applications for molybdenum steels include axles, shafts, steering knuckles and steering arms. During recent years, the tonnage of carbon-molybdenum steels consumed by the motor industry has advanced steadily. The possibility that the high manganese content of certain engineering steels may have to be replaced with molybdenum has been given consideration by the metallurgists of the motor companies.

While the national defense program will call for some changes in ordnance materials specifications, the direct demand for molybdenum steels for rearmament has not been so great as might seem likely at first glance, or as remembered from the great excitement over molybdenum during the War of 1914-18. If the present trend should continue, however, domestic consumption for this purpose will be considerably increased. The conservation of strategic elements will undoubtedly bring out bullet steels, armor plate and gun steels designed around molybdenum as the principal alloying element. Developments along these lines, while obviously of a confidential nature, have already passed the preliminary stages.

Oil well drilling and oil refining continues to create a growing demand for molybdenum steels. With oil wells going down faster and deeper every year, the need for high strength, quality steels to prevent costly failures is readily appreciated. In addition, increased cracking temperatures and pressures and a demand for improved service life have justified the use of molybdenum steels in oil refineries on a basis of their elevated temperature strength and resistance to creep. Steels containing 7% chromium with 0.50% molybdenum are now being employed in applications requiring better corrosion resistance at elevated temperatures than given by the more conventional 5% chromium steels. The successful welding of high chromium sheet linings to creep resistant carbon-molybdenum plate for pressure vessels was an outstanding commercial accomplishment during the past year.

Other significant new developments include *(a)* the use of a 3% molybdenum, 0.15% carbon steel for molds, *(b)* improved acceptance of a copper-manganese-molybdenum die steel that can be flame hardened in position, eliminating the use of inserts in certain forming dies, and *(c)* the use of a 5% chromium, 1.50% molybdenum steel for die casting dies.

Both 9% and 6% molybdenum high speed steels have received increased attention during the past year, and these steels may be expected to assume greater importance if a considerable price advance or a tungsten shortage should make an appearance.

Among many developments in cast iron calling for the use of more molybdenum in both as-cast and heat treated irons, it is appropriate to mention a molybdenum-vanadium iron, recently developed, that has exhibited unusually high strength with low accompanying hardness and good machinability. Cylinder heads, timing gears and manifolds are logical applications. The use of molybdenum irons for flame hardened dies and lathe beds is increasing and it has been reported that, under certain circumstances, adequate depth hardening can be obtained without a water quench. "Wheelabrator" blades containing 10% molybdenum have established some remarkable service records in the foundry.

During the past year, there have been considerable data added to the metallurgists' fundamental knowledge of the behavior of molybdenum steels. As a result of research work carried on over a period of years, "S-curves", so called, describing the transformation rates at constant subcritical temperatures, are now available of all the better known S.A.E. molybdenum steels for the guidance of the metallurgist and heat treater. While these data are not yet capable of indiscriminate application, they do represent a distinct advance in our permanent store of knowledge, and have already contributed to the solution of many shop problems.

It had to be Ductile and Still Machine Fast—

SPEED CASE STEEL *Solved the Problem!*

SPEED CASE PERFORMANCE RECORD

NAME OF PART COMMUTATOR SHELL

	PREVIOUS PERFORMANCE	SPEED CASE PERFORMANCE
MATERIAL	2-5/16 Rd. 1112	2-5/16 Rd. SPEED CASE
MATERIAL COST	$4.05 cwt.	$4.40 cwt.
MACHINE COST	$103.00 - 1120 pcs.	$81.00 - 1120 pcs.
HEAT TREAT COST	None	None
STRAIGHTENING COST	None	None
GRINDING COST	None	None
MISCELLANEOUS COST	$5.00 - 1120 pcs.	None
NET COST PER PART	$.1687	$.1508
PARTS PER TON STEEL	1120	1120

NET SAVINGS PER TON OF STEEL USED $20.04

SUMMARY MACHINING DATA

S.A.E. 1112 - 2 min. 9 sec. - 28 per hour - 1 Tool Grind 10 hrs.

SPEED CASE - 1 min. 49 sec. - 35 per hour - 1 Tool Grind 20 hrs.

SKETCH OF PART

Customer changed from S.A.E. 1112 to SPEED CASE to obtain necessary ductility for deforming. SPEED CASE deformed without cracking. See actual photographs below.

Part after Deforming

Part before Deforming

Machines FAST...

SPEED CASE STEEL machines as fast as High Sulphur Bessemer Steel X1112.

• *and DUCTILE, TOO!*

SPEED CASE STEEL is as ductile as any of the Low Carbon Open Hearth Steels — X1314, 1020, etc.

"SPEED CASE Did the Job 100%!"

• SPEED CASE STEEL has solved many manufacturing problems involving a combination of *Machinability* and *Ductility*. The above part required great ductility and still had to *Machine FAST*. *SPEED CASE STEEL* results were 100% satisfactory. "Speed Case" can increase *YOUR* production also.

Sole Licensee for Eastern States

THE FITZSIMONS COMPANY

YOUNGSTOWN, OHIO

Licensor

MONARCH STEEL COMPANY

HAMMOND CHICAGO INDIANAPOLIS

MANUFACTURERS OF COLD FINISHED CARBON AND ALLOY STEEL BARS!

Composite Steels

(Continued from page 383)

B — Pressure Welding

B-1. Non-ferrous metals and alloys are pressure welded to steel backing by rolling together at a high temperature.

Nickel, Inconel, and Monel clad — Lukens Steel Co.

Everdur clad — Republic Steel Corp.

Copper clad — Various.

Silver clad — Handy & Harman

B-2. A pressure welded bond between stainless alloys and mild steel is obtained by inserting an ingot iron sheet between the alloy and the mild steel and rolling the assembly to gage.

Plykrome — Plykrome Corp.

B-3. A pressure welded bond between stainless alloys, toolsteels, and alloy steels and mild steel is obtained by rolling together a stainless alloy plate electroplated with pure iron on the side in contact with the steel and a steel plate.

Silver-Ply Clad Steel — Latrobe Electric Steel Co. — Jessop Steel Co.

C — Fusion Welding

C-1. Overlapping beads of weld metal are deposited on the surface of a steel slab by oxyacetylene, atomic hydrogen, or electric arc welding. The surfaced slab may be rolled to plate and retains the alloy deposit on the deposited surface, or used as welded.

Kelkalloy — M. W. Kellog Co.

Stelliting and hard surfacing — Open.

Lead linings in steel drums, etc. — Lead Lined Iron Pipe Co.

C-2. A fusion bonded deposit of a secondary metal is fused with a carbon arc from a mixture of metallic forming material to the surface of a steel slab. The secondary metal is retained as a cladding on the plate or sheet after rolling to gage.

Kinkead's process.

C-3. A combination fusion and casting process employs a soft steel slab as one side of a narrow mold. An ingot of desired composition, bonded to the slab, is built up in the mold. An automatic welding head which makes a traverse in the mold supplies the metallic forming material. The composite slab thus formed is then rolled to gage.

Pluramelt — Allegheny Ludlum Steel Corp.

D — Electric Resistance Welding

D-1. A composite plate is fabricated by electric resistance spot welding a finish rolled alloy sheet to a rolled steel plate. No additional rolling of the composite is required. Two variations of this process include:

Resistance spot welds on close centers — A. O. Smith Corp.

Overlapping spot welds — Babcock & Wilcox Co.

D-2. Butt-weld two slabs over the entire surface and roll to gage.

Various bimetals — W. M. Chace Co.

6TH Carboloy Announces PRICE REDUCTION!

Plus New "Universal" Standard Tools For 80% of all Turning, Boring, Facing Jobs

Since the year when Carboloy tools were first introduced it has been the expressed aim of Carboloy Company to pass on to industry savings resulting from increased consumption and manufacturing efficiencies. As a tangible result of this policy, five major price reductions were put into effect between 1929 and 1939.

For a number of years, however, we have realized that if our ultimate goal of reducing the price of Carboloy cutting tools to a level that would make them available for the widest possible use, mass production methods of manufacture, through greater standardization, would have to be effected.

Towards this end one of our major activities has been to determine the minimum number of grades and the simplest line of tools that would be applicable to a substantial majority of carbide tool applications.

New $1,000,000 Plant Part of Program

Concurrent with this we inaugurated a long range program of manufacturing development to establish maximum efficiency for standardized production. This culminated in the expenditure of a million dollars on a new plant and equipment completed last spring, having a production capacity of ten times the amount of cemented carbide then consumed by industry, with provisions for expanding metal production to many times that amount.

Mass Production of Standard Tools Now Possible

Today we are happy to announce that this program has been completed. One of the outstanding results of this program now made available to industry is a line of standardized tools at prices that would have seemed beyond the realm of possibility only a few years ago. Indicative of the extent to which standardization has been developed is the fact that these tools—covering 80 per cent of all carbide tool requirements—comprise but five styles in only three grades—two for cast iron, and one for steel.

General Price Reduction on Carboloy Metal

A further result of this standardization program is that—because of the anticipated wider scale use of carbide tools—the cost of producing basic cemented carbides can be reduced to such an extent that we are able to announce the sixth general price reduction on carbide metals. This affects special tools, dies for working wire, bar, tubing and sheet metal, Carboloy wear-resistant inserts, etc., in proportion to the amount of Carboloy metal used in each product.

✓ Check These NEW Standard Tool Prices Against Any Other Cutting Alloy!

(Three styles illustrated)

~~$6.82~~ NOW $2.65

New Style 4
Size ½" square
(1⅛ x 1¼ x ½ Carboloy Tip)

~~$8.66~~ NOW $3.95

New Style 13
Size ½" square
(1½ x ⅞ x ½ Carboloy Tip)

~~$9.58~~ NOW $4.70

New Style 1
Size ½" square
(1½ x 1⅛ x ½ Carboloy Tip)

ALL TOOLS GROUND READY FOR USE (STEEL CUTTING TOOLS INCLUDE GROUND-IN CHIP BREAKER)

Write for New Price Sheets

CARBOLOY COMPANY, INC., 11105 E. 8 Mile Road, DETROIT, MICH.

CHICAGO • CLEVELAND • NEWARK • PHILADELPHIA • PITTSBURGH • WORCESTER, MASS.

Canadian Distributor: Canadian General Electric Company, Ltd., Toronto

CARBOLOY TUNGSTEN CARBIDES TITANIUM CARBIDES TANTALUM CARBIDES

ARISTOLOY STEELS

All ARISTOLOY *executives are located at the plant-for quicker action and closer cooperation on your alloy steel requirements*

WE TALK IT OVER ACROSS THE DESK . . . NOT ACROSS THE COUNTRY

All Aristoloy Executives and Department Heads have their working headquarters where Aristoloy Steels are made—at our Warren, Ohio plant. Talking it over across the desk, there's an easy, every-day interchange of information and experience. Centralized organization makes for closer cooperation, with less chance for error, delay, and misunderstanding. Aristoloy steel makers make steel *on the job* — not by remote control.

COPPERWELD STEEL COMPANY, WARREN, OHIO

Visit us at the
METAL SHOW
October 21-25, 1940
CLEVELAND, O.
Stop at our Aristoloy Exhibit—Booth F-20—and play "Aristoloy". You can't lose.
Prizes for high scores

ARISTOLOY S.A.E. ALLOY BILLETS AND BARS; AIRCRAFT QUALITY STEELS; OXIDATION AND CORROSION RESISTING STEELS; TOOL AND SPECIAL STEELS; STAINLESS STEELS

Why do it the

★

For prompt action call the nearest Carnegie-Illinois office.

Hard Way ?

★★ If your part in the preparedness program involves new problems in the selection and working of steels . . . *use this service*

IF you are being asked to turn from familiar peacetime manufacturing and throw your best efforts into the production of materials for national defense you have no time for trial-and-error methods. Speed is the vital element.

What you want to know is, what are the right steels for your new and unfamiliar requirements—and how they can be put through your manufacturing processes with the least waste, trouble and delay.

Fortunately, we are in a position to supply this information. Here at Carnegie-Illinois we have developed a corps of industrial "trouble-shooters"—engineers and metallurgists whose special job is not to sell steel but to help industry use it more *efficiently*. Their intimate knowledge of the constantly changing steel picture will safely guide you through the complex problem of proper steel selection. Their practical experience with the most advanced shop methods in using the many new and special steels now available will help you avoid time-wasting errors.

In working on your problems, these men can call upon the facilities of the most completely equipped research laboratories and the finest steel-making plants in America. Their advice can be entirely unbiased because they have the most comprehensive range of metallurgy's finest steels from which to choose.

This service is not new. It was initiated long before the present emergency. It is seasoned, tried and widely experienced. We offer it freely to any manufacturer who is anxiously studying unfamiliar blue prints and is seeking a practical way out from a situation that bristles with new problems. We believe we can help you. We welcome the opportunity.

CARNEGIE-ILLINOIS STEEL CORPORATION

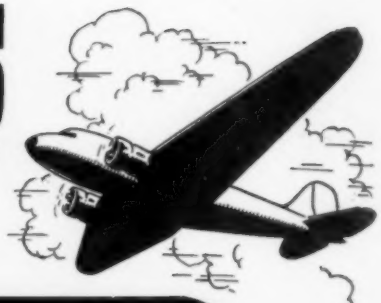
Pittsburgh and Chicago

Columbia Steel Company, San Francisco, *Pacific Coast Distributors*
United States Steel Export Company, New York

UNITED STATES STEEL

SPECIAL STEELS

for the Aircraft Industry!



American Aircraft Builders, like American Motor Car Manufacturers, will always find "INGERSOLL"

"A Dependable Source of Supply"

INGERSOLL
SPECIAL STEELS

Armor Plate . . . Alloy Steels . . .
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TEM-CROSS Cross-Rolled Steel . . .
Tillage Steels . . . Shovel Steels . . .
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High Speed Steels, etc.

Inquiries are invited

INGERSOLL
STEEL & DISC DIVISION
BORG-WARNER CORPORATION
New Castle, Indiana

Plants: New Castle, Indiana; Chicago, Illinois; Kalamazoo, Michigan; Chicago Heights, Illinois

4,000,000 BRASS SCREWS

FROM THESE

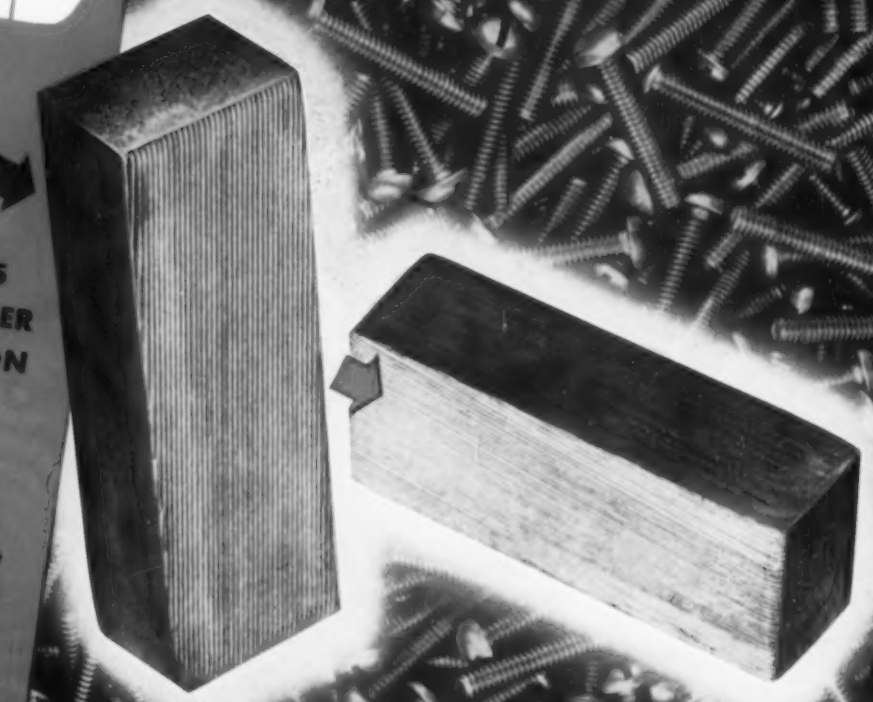
AIR HARD DIES

. . . TEN TIMES THE PREVIOUS PRODUCTION . . . AND ANOTHER CUSTOMER STANDARDIZES ON THIS REMARKABLE

VASCO STEEL

We're speaking *on the record* when we say "AIR HARD can set new records in *your shop*". . . for longer runs between grindings . . . longer total die life . . . better profit! Why not have the VASCO Man show you where this deep-hardening, non-deforming, easy-machining modern die steel will best benefit *your* operations?

"TOPS IN TOOL STEELS"



Vanadium-Alloys STEEL CO. LATROBE, PA.

Attention

Designing and Production Engineers!

. . . there is a deep drawing high tensile steel for high speed production line parts and products . . .

N-A-X

High Tensile

. . . and it has unusual high resistance to impact, fatigue, shocks and stresses, at normal as well as at sub-zero temperatures

Realizing the need for a high tensile low alloy steel that combined cold forming and drawing properties with strength, excellent weldability, resistance to corrosion and abrasion, Great Lakes metallurgists undertook to provide such a steel. The result, N-A-X HIGH TENSILE, possesses all of these characteristics and its forming properties approach that of deep drawing mild steels.

Of major importance to users of high tensile steel, and particularly designing and production engineers, is the unusually high resistance N-A-X HIGH TENSILE has to *impact* and *fatigue*, at normal as well as at sub-zero temperatures. This means that parts and products made of N-A-X HIGH TENSILE can be cold formed readily, usually without intermediate annealing, and have the stamina to stay on the job longer with less replacement costs. N-A-X HIGH TENSILE also has excellent forging, machining, heat treating and carburizing properties.

In scores of very difficult production line applications, in many of which other high tensile steels have failed, N-A-X HIGH TENSILE is being used and receiving the acclaim of manufacturers.

If you want all the advantages of a high tensile steel, plus the cold drawing and cold forming properties approaching those of deep drawing mild steel, specify and get N-A-X HIGH TENSILE.

Great Lakes engineers are available to show you how you can use this really *superior* high tensile steel to advantage. One will be glad to call at your convenience—no obligation. Wire, write or telephone for one today. Great Lakes Steel Corporation, Detroit, Michigan.

GREAT LAKES STEEL CORPORATION——DETROIT, MICHIGAN

Boston, 460 Statler Office Building; *Buffalo*, 1000 Walbridge Building; *Chattanooga*, 18 Volunteer Building; *Chicago*, 1026 Builders Building; *Cleveland*, 820 Leader Building; *Dayton*, 1401 Third National Bank Building; *Indianapolis*, 1215-17 Circle Tower; *Minneapolis*, 714 Midland Bank Building; *New York*, 405 Lexington Avenue; *Philadelphia*, 407 Liberty Trust Building; *St. Louis*, 3615 Olive Street; *San Francisco*, 824 Sharon Building; *Toledo*, 906 Edison Building. *Montreal, Quebec*, Drummond, McCall & Co., Limited; *Toronto, Ontario*, Peckover's, Limited.

division of NATIONAL STEEL CORPORATION

Executive Offices, Pittsburgh, Pa.

I can tell you a dozen reasons why we've shifted to MO-MAX.

AND the twelfth is the most important of the lot. We finally shifted to MO-MAX because our Superintendent kept dinging into my ears that we'd get twenty per cent more efficient high speed tools on an average by making them of MO-MAX steels. He was right, but that's not all. He was persistent. He not only knew, but he was all steamed up to do something about it. That's what I want to impress on you. You know the MO-MAX steels. Others in your plant know about them. You'll never get credit for knowing if you don't translate your knowledge into action. Twenty per cent more efficient tools are not to be sneezed at. Don't rest till you get action. It's your best chance to guard your own future by promoting your employer's. If you don't, somebody else will. Go to it.

MO-MAX

TRADE MARK REG. U S. PAT. OFF.

MOLYBDENUM-TUNGSTEN HIGH SPEED STEELS

Leading steel companies can supply you with their licensed brands of MO-MAX. For booklet with technical data and sources of supply, write The Cleveland Twist Drill Company, Cleveland, Ohio.

218

LATROBE

The BETTER Tool Steel
18-4-1
Electrite No. 1
HIGH SPEED STEEL
HIGH SPEED STEELS
for every need
ELECTRITE NO. 1
ELECTRITE NO. 19
ELECTRITE VANADIUM
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ELECTRITE COBALT
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Stocked in Principal Cities
LESCO
Users of high speed steels who are contributing their part to the national defense program will find ELECTRITE No. 1 fittingly adapted to this new tempo of production.
This 18-4-1 High Speed Steel possesses a maximum of red hardness and wear-resistance ideal for quality cutting tools. It responds readily to heat treatment, has a highly uniform grain structure and is of maximum density....factors which result in uniformly sound, tough steel!
Ask for latest bulletin on Latrobe Electrite No. 1 high-speed steel.

Latrobe ELECTRIC STEEL COMPANY

MAIN OFFICES and PLANT •• LATROBE • PENNSYLVANIA

COLMONOY

Hard Surfacing Alloys and Overlay Metals

The increased use of COLMONOY hard surfacing alloys in the metal industry is open acknowledgment of superior qualities of abrasion resistance. Comparative performance records show substantial savings over previous operations.

COLMONOY, with its diamond-like crystals of Chromium Boride, is available in many forms, and various degrees of hardness. Our engineers are competent to discuss the proper application of COLMONOY to meet your individual requirements. Your letter will receive prompt attention.

WRITE FOR CATALOG

Contains full information concerning all the various grades of COLMONOY *that meet every hard-surfacing requirement*

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Why You Should Specify

COLMONOY

Nickel Base Hard Facing Alloy

1. Gives longer life.
2. Resists wear, corrosion and galling.
3. Applies more easily.
4. Less facing material required.
5. Smoother flowing.
6. Lower melting point.
7. Less welding time required.
8. Less pre-heating required.
9. Applies to all ferrous base metals.
10. Finishes to a high polish, minimizing friction.
11. Can be hot wiped.
12. Does not service check.

Introducing—

Super-Y★

The Modern Metal

An Entirely New Level of Ferrous Castings

1. Tough as Steel
2. Machinable as Malleable
3. Smooth as Cast Iron

Minimum Guaranteed Physicals

Tensile Strength—60,000 lbs. per sq. in.
Yield Point—44,000 " " " "
Elongation—18% in 2 in.

Completely Graphitized — Not Pearlitic

See Us in Booth I-38 at the Show

Take Home A Test Bar and Check Our Claims

Chicago Malleable Castings Co.

MANUFACTURERS OF
SUPER-Y — MALLEABLE IRON — CAST STEEL
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Columbia TOOL STEEL

PREPAREDNESS —

With industry's new tasks tool-making materials are of added importance.

Columbia is ready to assist with the best possible materials, complete useful information and able sales-service men to help users get the fullest advantage of these products.

It pays to use Good Tool Steel.

COLUMBIA TOOL STEEL COMPANY

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Geared for EMERGENCY PRODUCTION
B & L
FREE-MACHINING STEELS
STEEL moves into first place as an essential industry . . . its products vital to national defense, as well as to peace-time prosperity • That the efforts of a united nation may not be "too little nor too late," American manufacturers are marshaling their resources for "total production" • B & L Free-Machining Steels are a prime aid in this rapid expansion of output • They are specially developed for increasing machine efficiency without sacrifice of quality or safety • Their uniformity assures better products, longer runs and lower costs in fabricating machine parts • B & L Cold Finished Bar Steels are available in a full range of grades . . . . Bessemer and Open Hearth, leaded and non-leaded, for all demands of modern service
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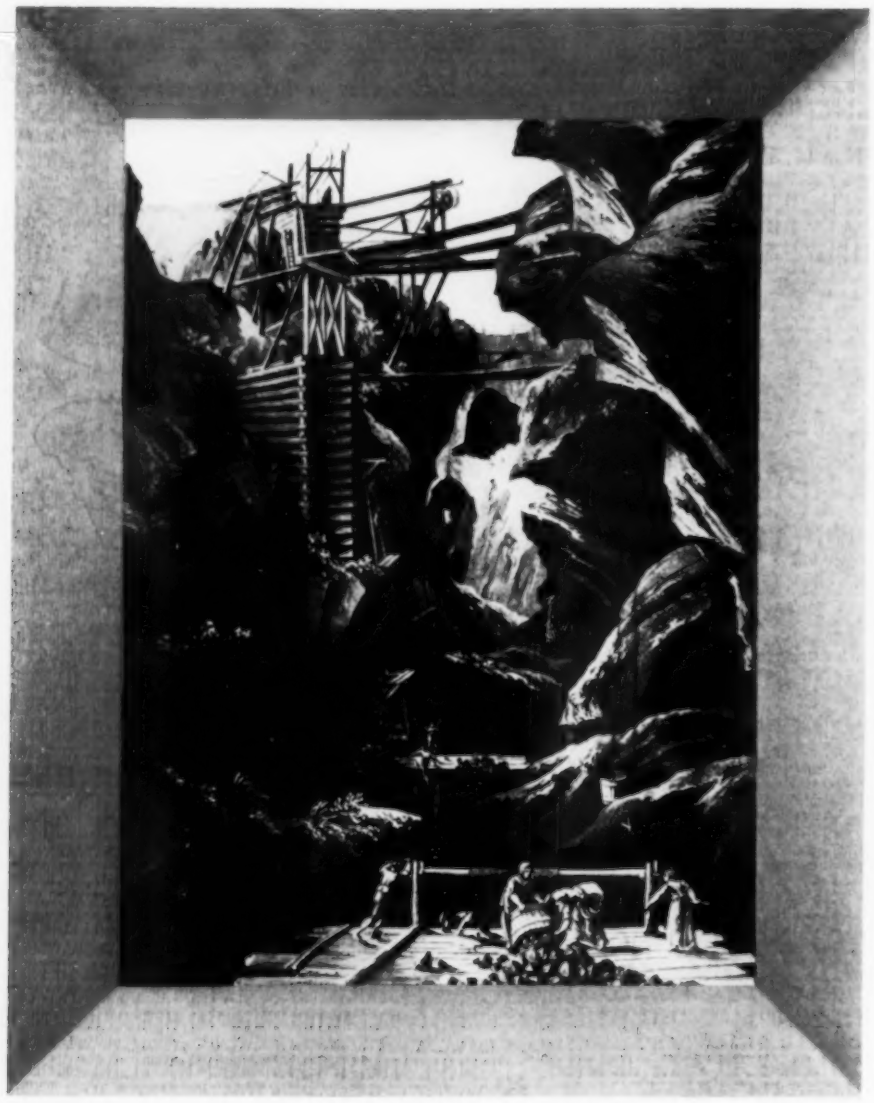

Iron ore mining in an Uddeholm mine centuries ago.

Throughout 273 years of War and Peace, Uddeholm has never deviated from its original pursuit . . . the goal of superior steels! « « « And Uddeholm Steels have, during the years, contributed their small share in the building of America. Thus, even in these troubled times, 14 stocks of Uddeholm Tool Steels are continuing to serve American Industry in its forward march.

UDDEHOLM COMPANY OF AMERICA, INC.

155 East 44th St., New York, N. Y. **Exclusive Tool Steel distributors**

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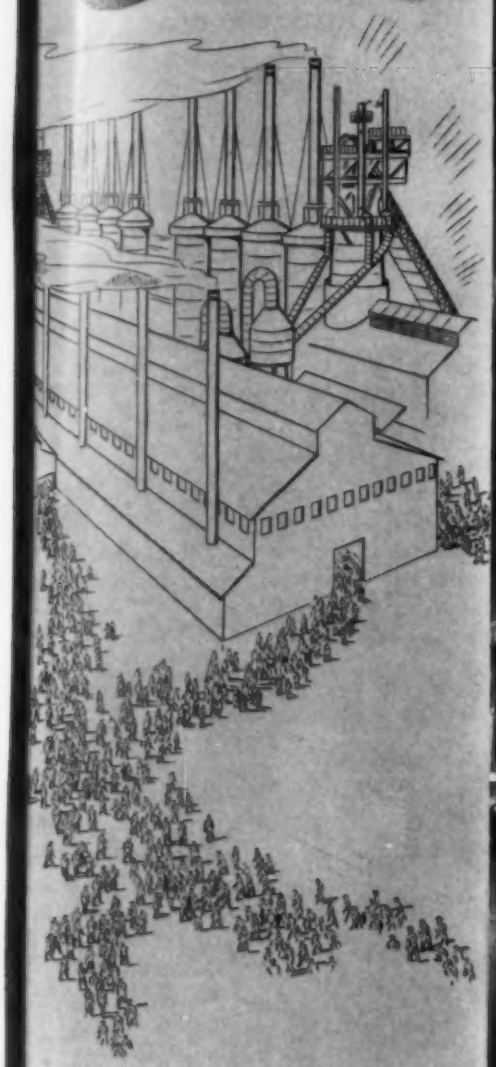
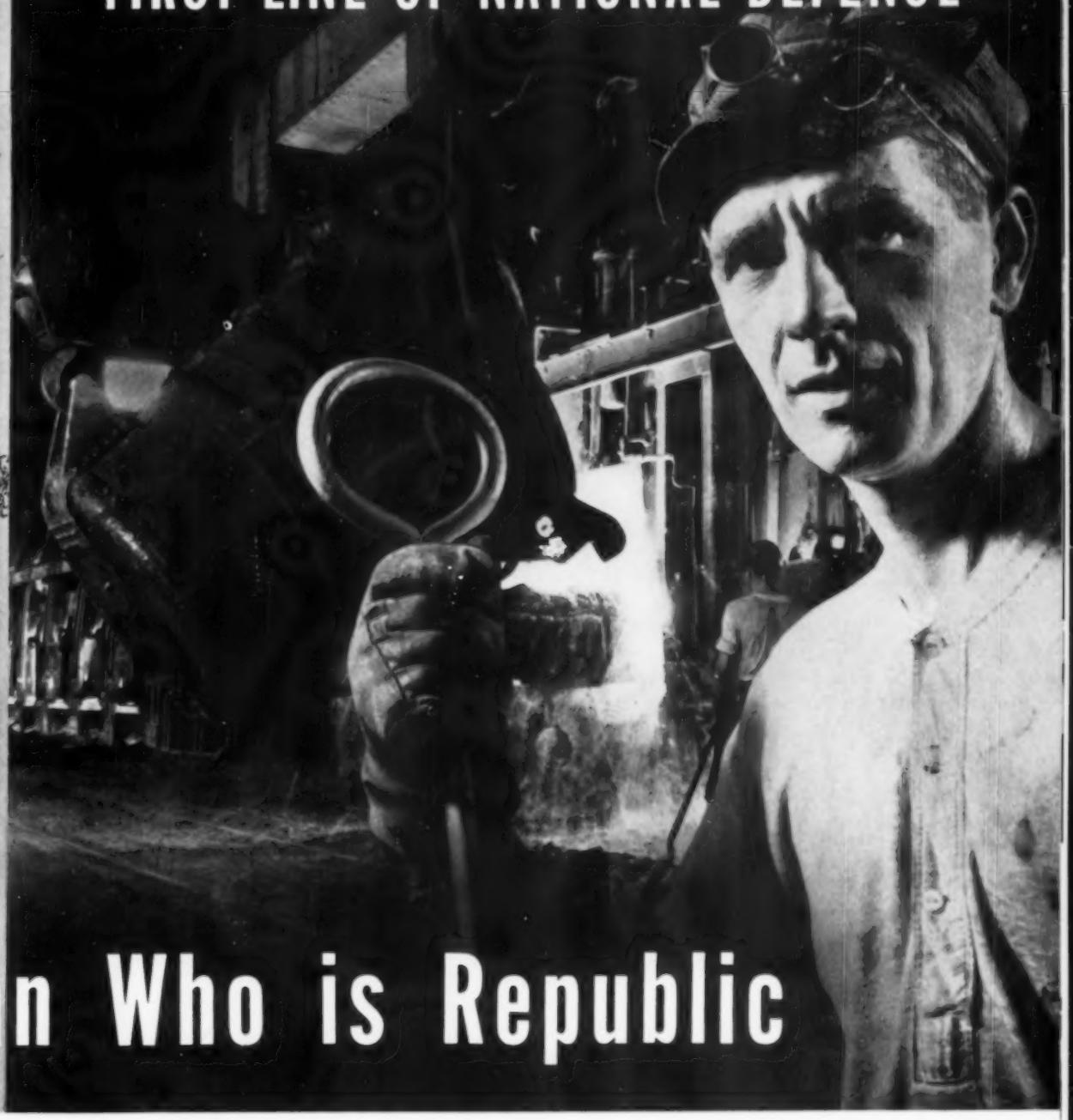
Steel — FIRST LINE OF NATIONAL DEFENSE





The Man Who is Republic

No bugle wakes him from his morning sleep.

No uniform tells all who see him that he is defending the liberty of America.

No beribboned medal shows his work well done.

But there he is—a typical American—55,000 of him in round numbers—working in Republic plants, mines, offices and warehouses in 35 states.

This is the man who is Republic—who operates the world's largest blast furnace and the widest continuous strip mills—who is the world's largest producer of alloy and stainless steels, of "aircraft quality" steels, of electric weld pipe and tubing—who is trained and equipped to produce in a wide variety of types and forms, huge quantities of ***steel—first line of national defense.***

To emphasize the vital importance of steel in today's emergency and its ability to meet the demand, Republic will display at the National Metal Show various units of defense equipment improved through the use of new and better Republic steels. See this exhibit at Space A-10.

REPUBLIC STEEL CORPORATION • CLEVELAND, OHIO

Berger Manufacturing Division • Niles Steel Products Division • Steel and Tubes Division • Union Drawn Steel Division • Truscon Steel Company

TO HELP YOU PRODUCE STAINLESS PARTS FOR LESS MONEY

SUPPOSE you could blank and form stainless with an assurance of fewer shop hold-ups and reduced unit costs. Wouldn't this mean that more of your products could be given the extra sales appeal of stainless steel—or the additional lightness and strength? Wouldn't this help you in putting over your pet ideas? If so, here are facts:

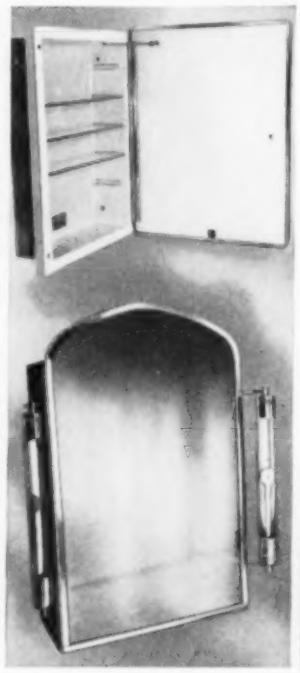
THE PLACE TO LOOK FOR LOWER STAINLESS COSTS IS BEHIND THE CURTAIN OF PRODUCTION DELAYS.

When presses are stopped because of trouble with the stainless strip, output suffers and costs rise. Yet the common interruptions—those caused by excessive burrs, ragged edges, tears, wrinkles, scratches, premature die wear, etc.—can be materially reduced or almost entirely avoided. With two precautions, it is usually possible to turn out stainless parts at speeds comparable with mild steel production rates.

The first precaution is to remember that stainless averages 50% stronger than mild steel. In fact, the higher physical properties of stainless may be the very reason why you are using it. On the other hand, these higher physical properties do call for more attention to proper tooling and lubrication, and they may call for the use of one size heavier press, or stock of a slightly lighter gauge.

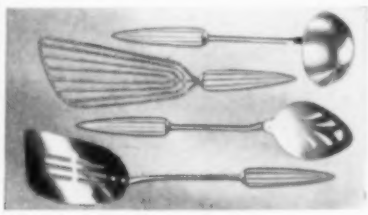
The second precaution is to pick the right stainless for the job. That's where Carpenter comes in with stainless strip analyses specially developed for easy-working qualities. Each grade is a soft, clean blanking strip, uniform in gauge, temper, color and finish. Each is an electric furnace steel made under the close control customary in a tool steel mill. We believe it is our job, too, to help you select from these steels the one that best meets shop *and* service requirements.

As both a tool steel and stainless steel mill, Carpenter is unusually well prepared to aid you in meeting both the above precautions. Carpenter representatives can offer dozens of useful hints on tooling up and can work with your men on smoothing out trouble with stainless stock. They can put in your hands a great deal of helpful literature on both subjects. That is an important dual service worth using.



"NO PLATING TO PEEL—EASIER FABRICATION"
These two bathroom cabinets were installed in a New York City housing project. Because they are trimmed with Carpenter Stainless No. 6, they will have a permanent good appearance—and yet fabricating costs are well within limits.

You can start to cash in now on these service facilities. We have prepared a very useful, quick reference Stainless Steel Slide Chart which we will be glad to send you without obligation. Pocket size, it gives you a quick summary of technical data on Carpenter and other stainless steels. If you do not already have this chart, send for your free copy today.



"SOFT ENOUGH FOR LADLES—SPRINGY ENOUGH FOR SPATULAS."
These attractive utensils are formed from Carpenter Stainless No. 6 at a cost low enough to sell in a highly competitive market—thanks to the clean blanking, fast forming characteristics of this steel. Carpenter Stainless Strip can be purchased in a variety of tempers—dead soft for drawing a ladle, or spring tempered for a spatula.

THE CARPENTER STEEL COMPANY...READING, PA.

Carpenter STAINLESS STEELS

BRANCHES AT Chicago, Cleveland, Detroit, Hartford, St. Louis, Indianapolis, New York, Philadelphia

"BECAUSE IT DRAWS BETTER THAN ANY 18-8 PREVIOUSLY TRIED"

That was the reason for using Carpenter Stainless No. 4, says the manufacturer of these soap dispenser parts. Notice that some of these parts are drawn as deep or deeper than the diameter.

more than corrosion resistance

FREE

TO STAINLESS USERS IN U.S.A.

THE CARPENTER STEEL COMPANY
133 BERN STREET, READING, PA.

Gentlemen: Without obligation, please send me your free Stainless Steel Selector Slide Chart.

NAME _____ TITLE _____
Please Print

FIRM _____
(Firm Name Must Be Given)

ADDRESS _____

CITY _____ STATE _____

In the search for better and better QUALITY

THROUGHOUT the history of American metallurgy runs the tireless search for better and better quality—cleaner, more homogeneous metals,—finer finished products. And the Titanium Alloy Manufacturing Company has been—still is!—a pioneer in this search.

Producing over 30 years ago, the first commercial Titanium Alloy for use in molten steel, TAMCO since then has developed TAM Alloys for practically every class of steel, as well as alloys for other metals.

The two TAM Ferro Carbon Alloys—TAM *Original* F. C. T and TAM Medium Carbon F.C.T.—are outstanding Titanium deoxidizers helping to produce superior steels, from the highest carbon down to the lowest carbon made! Supporting these leaders is a comprehensive list of TAM Alloys and Products for all needs of the practical metallurgist.

TAM 40% *Low Carbon* Ferro Titanium, TAM Foundry Ferro Titanium (for cast iron), TAM Webbite (for aluminum), TAM Cupro-Titanium (for copper), TAM Metallic Titanium, and TAM Metallic Zirconium. Also TAM Foundry Zircon Sand and TAM Zirconite "A", both super-refractory mold and core materials; and in addition to these many other refractories and cements.

A TAM Engineer is always ready and willing to assist your plant with accurate, up-to-the-minute information.

Come to the TAMCO Booth F-13 at the National Metal Exposition, Oct. 21 to 25, Cleveland. TAM Engineers will be glad to "talk things over".

THE TITANIUM ALLOY MANUFACTURING CO.

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23-27, Broomhall St., Sheffield, England

Cost Less Because They Last Longer

Any industry—*your* industry—may learn a valuable lesson from the manufacturers of Cast Steel Gears.

Their first cost is lower, for they may be designed for greatest strength exactly where needed, without excess weight. They require less machining, and where teeth are cast, there is little or no waste stock. Differential hardening of parts is practical and inexpensive.

And Cast Steel Gears wear longer. They start with uniform, homogeneous blanks, free from flow lines concentric with rim, which might cause tooth breakage. Desired mechanical properties may be specified in advance.

These same qualities, plus many others, may lead the way to improvements in your product. Investigate the ability of Steel Castings to save money—they provide extra strength without extra weight, cut down the number of parts, simplify assembly, cut machining costs, and provide exactly the mechanical properties you want.

Ask your own foundryman, or write Steel Founders' Society, 920 Midland Bldg., Cleveland, Ohio.

IMPROVE YOUR PRODUCT WITH

STEEL CASTINGS

THE FUNDAMENTAL REASON WHY

KENNAMETAL

is the best carbide for machining steel

Style No. 11 Tool with Chip Breaker

With the exception of KENNAMETAL, hard carbide tool materials for machining steel consist essentially of *mixtures* of titanium carbide (or tantalum carbide) with tungsten carbide, to prevent "cratering" of the tool tips. KENNAMETAL, however, is an intermetallic *compound* of tungsten-titanium carbide corresponding to the chemical formula $WTiC_2$, and is considerably stronger than mixtures of these hard carbide materials. Because of its superior strength, and because $WTiC_2$ is harder than mixtures of simple carbides, tools tipped with KENNAMETAL can take heavy, rough cuts, or interrupted cuts, without breakage, and do not "crater" or wear. Write for information today.

IMPORTANT NOTICE

KENNAMETAL tools cost no more than ordinary carbide tools—see our new price schedule.

McKENNA METALS Co.
156 LLOYD AVENUE
LATROBE, PENNSYLVANIA, U.S.A.

- HIGH SPEED AND CARBON TOOL STEELS
- HEAT RESISTING AND STAINLESS STEELS
- HIGH NICKEL STEELS
  Including Invar type minimum coefficient alloys
- PERMANENT MAGNET STEELS
- SPECIAL ANALYSIS STEELS

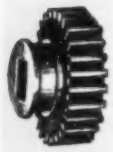
WRITE FOR COPY OF MAGNET STEEL BOOKLET

SIMONDS STEEL

SIMONDS SAW & STEEL CO., LOCKPORT, N. Y.

'FIVE-POINT' Deephard STEEL

'FIVE-POINT' *Deephard* PROCESSED STEEL PRODUCTS



THERE IS NO CLOSED SEASON ON WEAR!

- Your best weapon is 'FIVE-POINT' *Deephard* Processed Steel—use these dependable, wear-resistant products on vital moving machine parts.
- Save yourself the trouble and annoyance of costly and untimely shut-downs.
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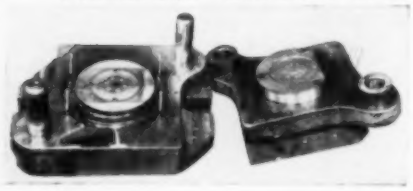

Male and female subpress die for blanking synchronous motor field plates from 2% silicon steel, .050" thick. Photo courtesy Lux Clock Mfg. Co., Waterbury, Conn.

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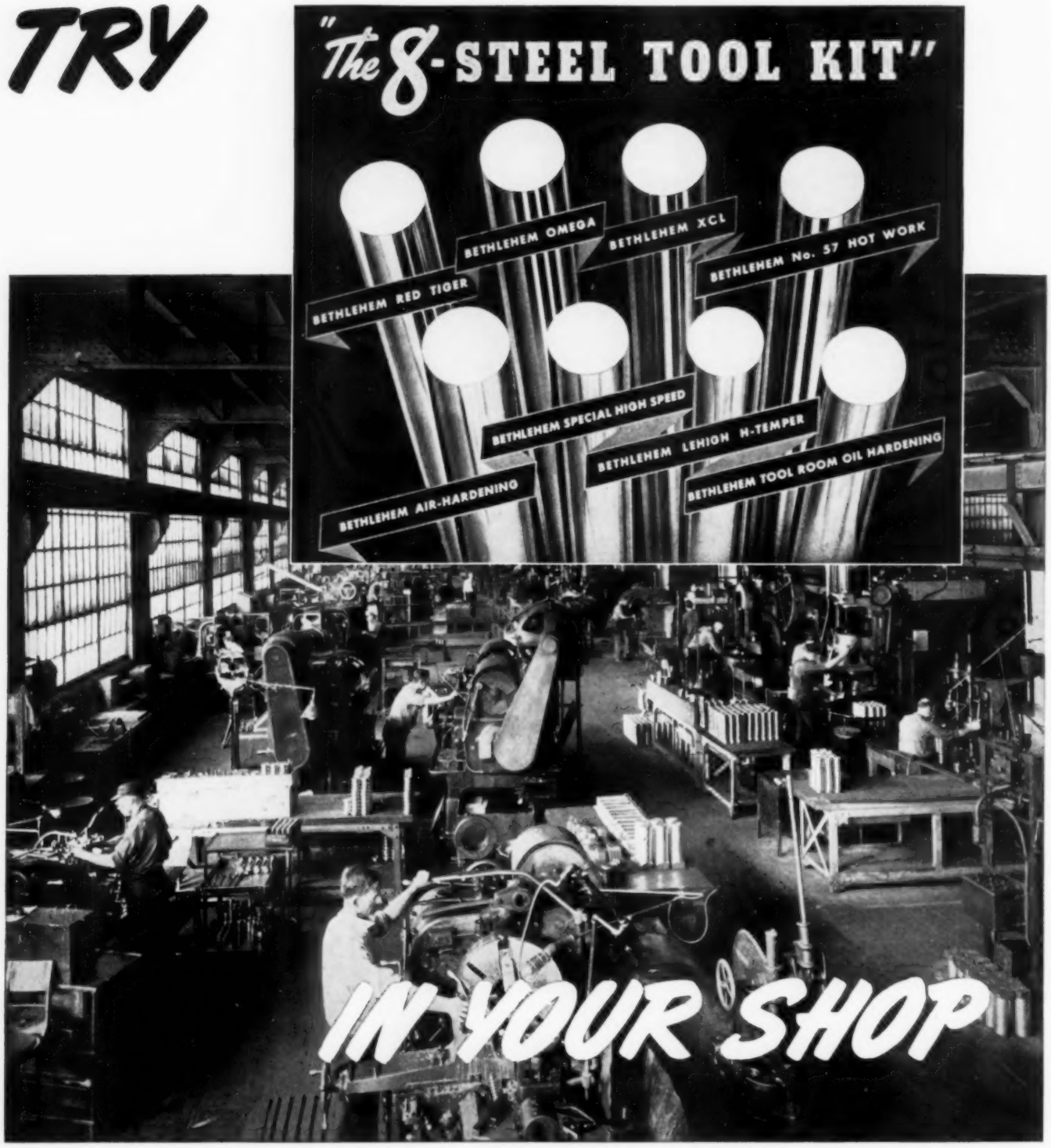

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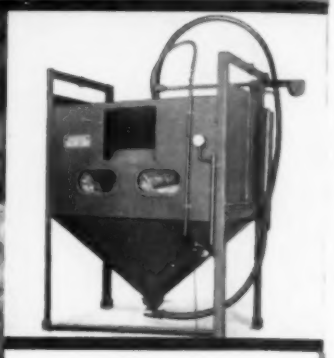

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Heat Treating and Finishing

The Fundamental Action — Transformation of Austenite

By Thomas G. Digges
Metallurgist, National Bureau of Standards

AUSTENITE, the condition in which a steel exists as a single phase, in most steels is stable only at an elevated temperature. In fact, the properties upon which much of the usefulness of steel depends are intimately related to the decomposition of the austenitic phase at some temperature below that at which it is stable. Hence the importance of this transformation, warranting the large amount of study which has been expended on it.

The structure and hardness of a steel which can be hardened by quenching may be pictured as being dependent on the temperature at which the austenite transforms during cooling. It is known that the *rate* at which the steel is cooled during the quench is important only in determining how *low* a temperature austenite can be cooled to before it begins to decompose (transform). If the austenite transforms at a relatively high temperature the product is coarse pearlite with a relatively low hardness. If the rate is sufficiently fast to cool the austenite unchanged to a low temperature, its decomposition product is martensite and the steel is fully hardened. Intermediate structures and hardnesses are obtained when the austenite decomposes in the intermediate temperature range.

Much study has been given to the rate at which austenite must be cooled to prevent its transformation to pearlite — that is, to harden it fully. This rate is influenced primarily by the steel's *(a)* composition, *(b)* grain size and *(c)* homogeneity.

Additions of alloying elements (including carbon) that dissolve in austenite usually retard its rate of transformation to pearlite and thus contribute to deep hardening or to an increase in "hardenability".

The grain boundaries of homogeneous austenite (that is, austenite in which carbon and alloying elements are in uniform solid solution and relatively free from inclusions) generally contain the nuclei that are effective in the initial transformation to fine pearlite (nodular troostite). These nodules grow radially towards the center of the parent grains. If the size of the austenite grain is large, the total surface area of the grain boundaries in a given piece of steel is smaller than though the average grain size were smaller, and the distance for the pearlite to grow is larger. It should be obvious that the rate of transformation of large-grained austenite to pearlite decreases with increase in the grain size.

However, in steels containing non-homogeneous austenite or a relatively large number of inclusions, the initial transformation of austenite to pearlite is not always confined to the grain boundary region but often takes place in the interior of the parent grain and then proceeds at various rates throughout the grain. Portions of the grain that are relatively impoverished in carbon or alloying elements have higher transformation rates than do the portions rich in these elements. Inhomogeneity of austenite may be the result of rapid heating, too low a heat treating temperature, insufficient time at temperature, low diffusivity of the alloying elements — to mention the main causes. For the steels containing non-homogeneous austenite or a relatively large number of inclusions the size of the austenite grains is not always a true index to its transformation rate or hardenability. This limitation to the importance of grain size should be borne in mind.

Induction Heating

By Martin Seyt

HIGH FREQUENCY induction heating for hardening, at least in a tentative way, started almost as soon as induction melting. Some interesting early work was done by Ajax Electric Co. in 1928 at The Midvale Co. in Philadelphia on the surface hardening of rolling mill rolls. Likewise production hardening of razor blade steel started about ten years ago at Gillette Safety Razor Co., Boston, in this manner: A long, small nichrome muffle was wound with copper tubes through which was sent 4800-cycle power from a motor-generator set, inducing current in the muffle and heating it. The passing steel strip was therefore heated principally by radiation from muffle walls which were heated inductively; it was quenched between water-cooled blocks at the exit end. The method was highly successful, controlled continuously and accurately by the magnetic characteristics of the hardened strip, and is now used exclusively for Gillette razors, some 18 furnaces being installed.

Lower frequency power, say the 1000-cycle current used in a melting furnace, has been used for heating larger pieces such as steel pipe. A similar application for tempering pinion shafts was in operation in one of the automobile plants several years ago. Currents ranging down to 60 cycles are now in use for heating restricted areas on small shafts, through and through, for hardening or normalizing, or for warming sleeves or gears prior to shrinking onto cold shafts.

As is well known, the tendency of higher and higher frequency currents is to crowd themselves more and more closely to the *surface* of the conductor. It is possible, therefore, to heat (and therefore harden) nothing but a thin surface layer by holding the steel part within a coil carrying a current of the proper characteristics. Some six or seven years ago it occurred to the engineers of the Ohio Crankshaft Co. that bearing areas could be so hardened, and the excellent service of the first trial shafts started a remarkable development of a new heat treating process adaptable to semi-automatic production schedules. Its advantages are that the equipment can be set in the machine line, it uses power only when it is needed, and heats only those portions of the part that need be heated. Heating is so quick and localized that a quenching spray must be built into the inductor blocks; this may seem to be a disadvantage, but it insures that there is no delay in the quench. High speed heating also practically eliminates surface oxidation, and symmetrical heating greatly reduces warping. High surface hardnesses on unaffected cores frequently enable the metallurgist to reduce or even eliminate alloy content in the steel parts, and thus save large sums in cheaper steels. Production lines now are operating on all sorts and sizes of crankshafts, camshafts, tappet ends, universal joints, and connector pins.

Applications are by no means confined to the automotive industry. In the manufacture of munitions, power at 1000 to 2000 cycles is used for heating a billet for the forging of shell. Heating is very rapid; for instance, two small tube-like "furnaces" will service a press making 3-in. shell, heating a 2½-in. bar to 2200° F. in 90 sec. High frequency power will also surface harden the finished projectile. All production operations such as the above are in sequence and automatically timed, so the attendant merely loads and unloads and presses a button. Some small parts are magazine fed — entirely automatic.

Motor generator sets are necessary for converting much power. Frequencies of 2000 and 3000 cycles have been common. Quite recently 10,000-cycle generators have become available, and this seems to be near the upper limit. Such high frequency power will give currents that hug the surface of a gear pinion so closely that the hardening follows the contour of the teeth almost as closely as in casehardened work.

Very high frequency currents are now available from mercury gap converters, but such sets are limited to relatively small power (25 kw., perhaps) and non-continuous operation because such a large proportion of the power put in must be radiated from the converters as heat. Equipment of this sort is valuable for heating small parts; simple inductor coils conforming to the outer dimensions of the part to be hardened are easily made. Ordinarily the piece is held inside the coil a few seconds and then dropped into a quench, or quenched through the coil the instant the power is off. Timing and centering should be fairly accurate to get uniform results.

An interesting and important variation promoted by Budd Induction Heating, Inc., is the internal hardening of such things as races in wheel hubs, roller bearing cones, and cylin-

der liners. A conforming coil is lowered *into* the bore properly arranged to throw an intense fluctuating field outside the coil, and this, in turn, induces heating currents on the inside of the surrounding steel part to be treated.

Production Quenching

By William J. Conley
Professor of Metallurgy, University of Rochester

AS will be pointed out in the lectures at the forthcoming National Metal Congress, there are too many variables involved in quenching, the individual effects of which are not understood, to justify a statement of fixed rules. The variables encountered are such that the control laboratory, in insuring metal of uniform chemistry, grain size and hardenability, is of prime importance in the uniform production of heat treated parts, even from the most carefully mechanized operations.

The common quenching mediums are water, aqueous solutions, oils, molten salts, gas and air. The last three materials seem to be growing in use.

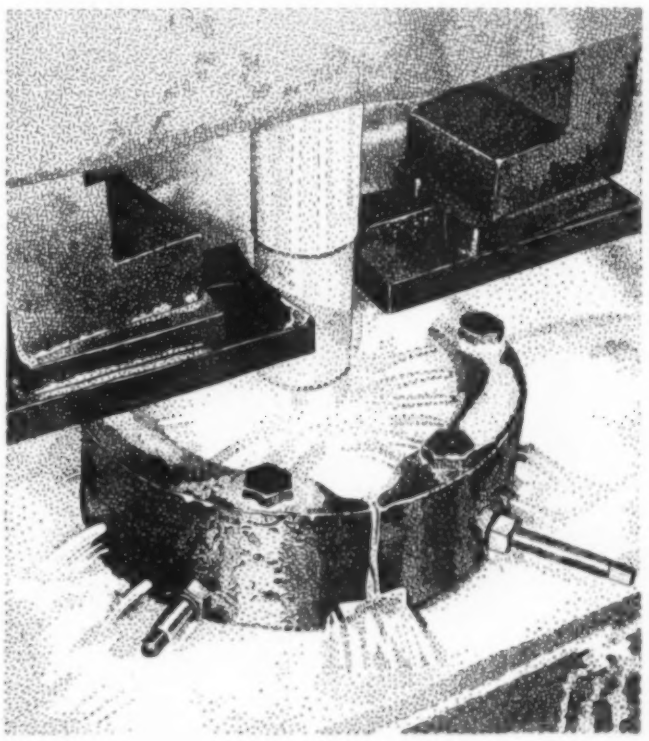
For the ferrous metals oil is by far the most common quench, the reason for this being that its temperature variations do not cause such serious fluctuations in the results as water quenches. The last cooling stage of steel is less rapid in oil, removing much of the danger of cracking. However, there is little agreement as to the desired qualities in an oil bath. In the same organization there may be disagreement about the merits of a given quench. One unit may be using one of the most highly recommended prepared oils while another will be using a cheaper byproduct from an oil refinery, each one apparently achieving equally good results. A review of the variables (size, shape, temperature of metal, and temperature and circulation of oil) shows that this situation should not be so unexpected.

An attempt to take advantage of residual heat in metal taken from the quench has led to many special operations usually designated as interrupted quenching. To be successful, it should be under very close control, timing being determined in the order of fractions of a second as a result of experiment. The most common quenching procedures are to water quench and then air cool or to water quench and oil cool.

For constant temperature quenching, low melting metals, mixtures of metals, salts, or mixtures of salts are used. Provision is made to keep the bath liquid, and at the required temperature by thermostatic control of the source of heat, which may be gas, oil or electricity. The problem in this field is to provide corrosion-proof refractory containers.

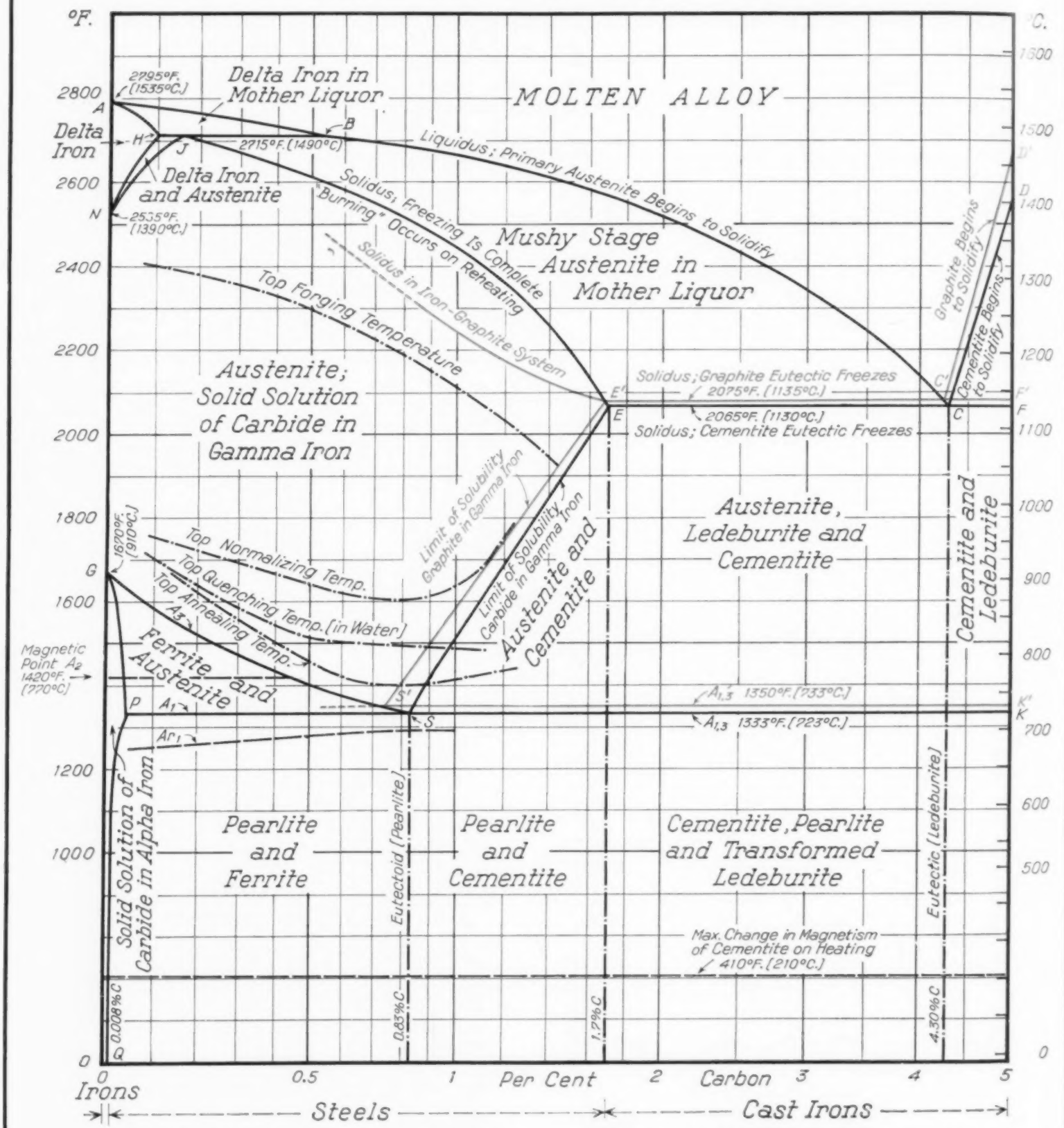
One of the variables, namely the temperature of the bath, can be controlled as accurately as economically desirable. In fact, the degree of control must be determined before the quantity of quenching material can be chosen. Cooling of the quenching bath can only occur by radiation, either natural or artificial. Large baths cooling work only intermittently may not be circulated at all. In other plants the oil is pumped from the quench tank back into a large storage tank, from which the quench is continually supplied, and radiation from pipes and storage tank is depended upon. Sometimes these pipes are built into the form of an air radiator, but such a scheme takes up a lot of space. Tubular heat interchangers are more efficient; the cooling medium is ordinarily refrigerated brine where an ample supply of cheap cold water is unavailable.

The fully automatic method for heat treatment is ideal for large scale production since each step in the whole cycle from hardening furnace through the final draw can be synchronized. However, unless the work is of the same type for long periods, wholly mechanical methods may not be satisfactory. Also the kind of machine used for quenching will depend on whether or not atmosphere controlled furnaces



Iron, Iron Carbide Equilibrium Diagram

Approximate Iron-Graphite Diagram in Red



Except as noted hereafter, lines are reproduced by courtesy of The Engineering Foundation from diagrams published in one of the Alloys of Iron Monographs: "Alloys of Iron and Carbon," Vol. I on Constitution, by Samuel Epstein.

Delta iron region and solidus by Frank Adcock, *Journal* of the Iron and Steel Institute, 1937-I.

Forging and heat treating temperatures from Recommended Practices, 1939 Metals Handbook.

Solidus in Iron-Graphite System according to Kaya, Honda and Endo, *Science Reports*, Tohoku Imperial University, 1925 and 1927.

Ar_1 according to Hoyt and Dowdell, "Metals and Common Alloys," for cooling rates of 1° C. in 3 sec.

Line GPQ according to J. H. Whiteley, *Journal*, Iron and Steel Institute, 1936.

Solidus in graphite system left of E′ as suggested by Harry A. Schwartz.

are used for the heating and whether accurate control of the stock is available through chemical and metallographic analysis. One finds a tendency to specify the finished parts according to physical properties, allowing enough tolerance so that the steel mill can furnish metal at lower cost.

Mechanisms commonly used for quenching (other than presses or clamps for individual pieces) utilize a chute leading from furnace to tank wherefrom the work is reclaimed by inclined conveyor flight or a power driven drum. Work on trays may be pushed along a Vee-shaped incline, or handled by elevators and submerged conveyors. Chute entrances are adapted for use with atmosphere controlled furnaces since the discharge end of the heating unit can be hooded through a vestibule directly into the bath. In this case special precautions must be used to circulate the oil in the hooded space.

Individual quenching machines can be arranged for any desired cycle of motions. Jets can be directed to locations requiring higher hardness, or to control warping. These methods must be worked out experimentally on uniform material. Uniformity of results and lack of distortion is as much a function of proper oil flow as of die pressure, although the latter helps hold the work while it is still plastic.

It is noted that there is a rapid growth in the use of special methods to produce localized hardening, differential hardening and rapid, accurately controlled heating. In these processes the quenching action is determined to a great extent by the heating cycle, as illustrated by induction, flame and electrically heated liquid bath heating. The introduction of inexpensive air hardening steels has made it possible to have the part remain in the discharge vestibule directly connected to the heating chamber and containing the same atmosphere. Water cooling of this vestibule allows the piece to harden in controlled atmosphere or really in a gaseous bath; it may be called gas quenching.

Hardenability Tests

By Walter E. Jominy
Metallurgy Dept., Research Laboratories
General Motors Corp.

HARDENABILITY tests as applied to engineering structural steels are of such recent development that only a few metallurgists have had time to try out more than one or two of the proposed schemes. As a result, there is some confusion as to the particular test best suited to a given application, so perhaps a brief statement of the various tests will be a useful preliminary to this discussion.

Probably the commonest and the one requiring the least equipment is the "immersion quench method". It consists of quenching round bars, sectioning these bars and then making a hardness traverse across the section. While it appears to require no special equipment it has been found that for accurate results a mechanical quenching means is necessary. Further, when quenching in oil, surface scale is undesirable; this requires either heating in a non-scaling atmosphere, or copper plating and heating in charcoal or carburizing compound. For the deep hardening alloy steels this method is rather cumbersome because very large sizes must be used and these require long heating periods and are difficult to section.

The "Burns, Moore and Archer method" is the application of the above method to a 1-in. round bar, water quenched, and its evaluation by a specific set of figures known as the "S-A-C" rating. Inasmuch as water is the quenching medium, moderate scaling can be endured and care in hand quenching gives good accuracy. This test is especially suitable for water hardening steels and cannot of course be used on steels which will harden through to the center when water quenched. It cannot therefore be used on most of the medium carbon alloy steels.

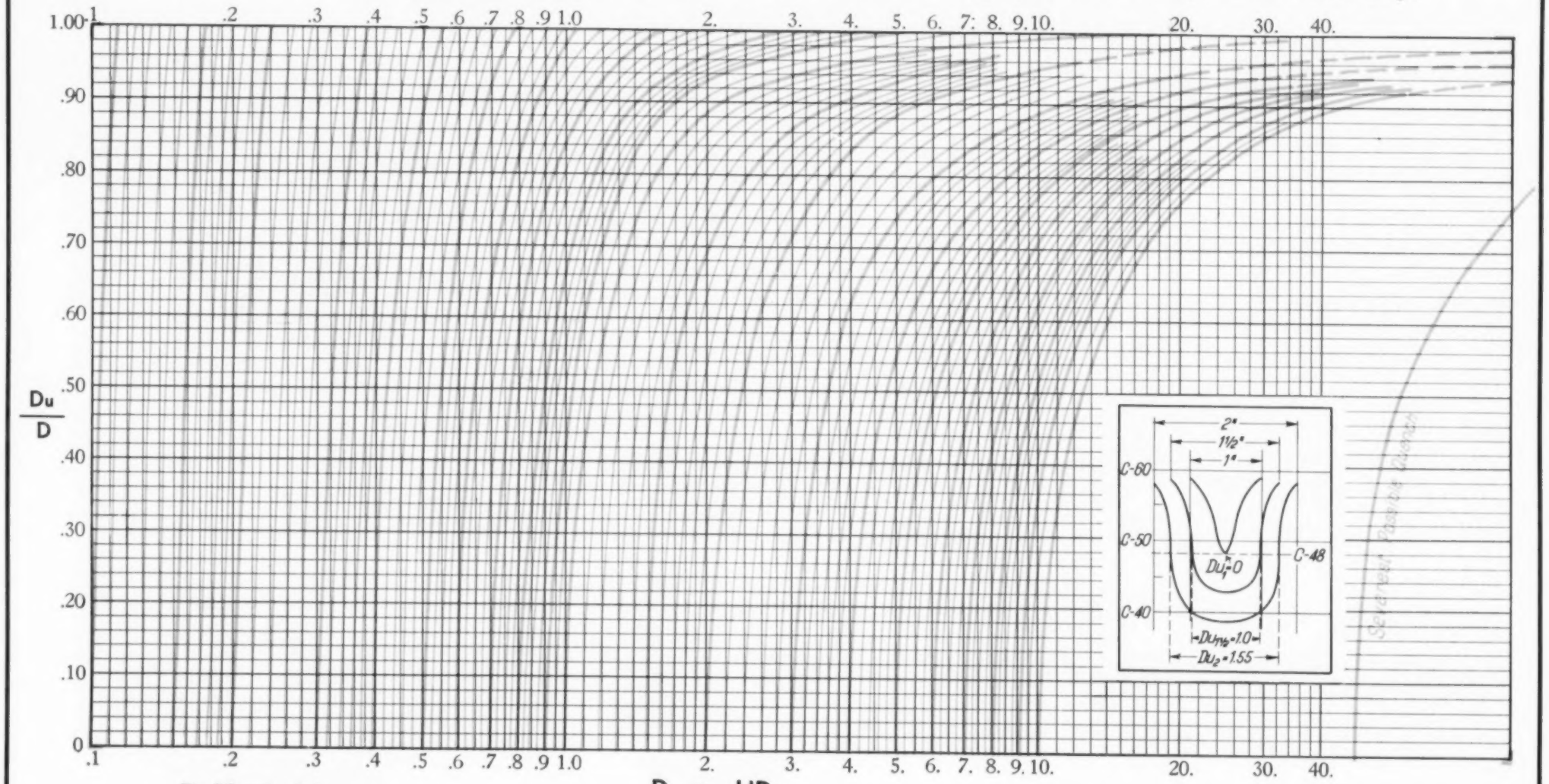
The "Shepherd P-F test" which preceded any of the standardized methods was originally devised for high carbon toolsteels and is the same type of test as that of Burns, Moore and Archer. In the Shepherd test a ¾-in. round is brine-quenched and sectioned, then etched with 50% aqueous hydrochloric acid to show the depth of hardness. Disks of stepped thickness may also be used; in either case the test is only useful for shallow hardening steels.

"Grossmann's method" is another application of the sectioning method in which several bars of different size must be hardened and sectioned in order to obtain the size of bar in which the center hardness changes abruptly with small changes in diameter. This bar size is called the critical size and is a measure of the hardenability of the steel. This method requires more labor than the others but the resulting determination is quite accurate.

The "end cooling method" used in General Motors Research Laboratory is perhaps the

Cooling Power of Quenching Baths

Curves whereby severity of quench (heat transfer equivalent H) can be estimated. Copyright, 1939, Carnegie-Illinois Steel Corp.



By Morris Asimow and Marcus A. Grossmann

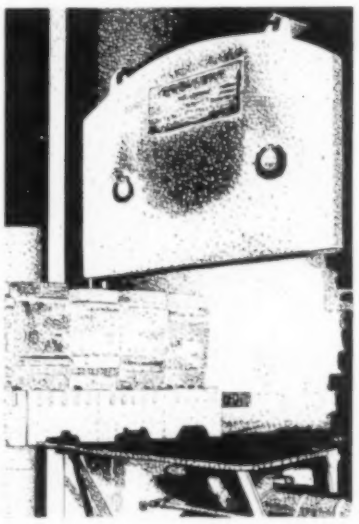
TO USE this chart, harden *at least* three bars of various diameters in the given medium at working temperature and circulation, and determine curves of hardness distribution, edge to axis, at midlength. In the example sketched in the inset above, D is 1, 1.5 and 2 in. respectively. At a selected hardness horizontal, as C-48, which intersects or touches all curves, determine the ratio $Du \div D$ between soft center and bar diameter. (Soft center diameter Du is 0, 1.0 and 1.55 in.; $Du \div D$ is 0, 0.66 and 0.77 respectively.) Lay a piece of tissue paper over the chart with its edge at the base line and plot $Du \div D$ against D for each bar size. Slide tissue paper right or left until these points fall on a single curve, which for this quench happens when D_1 is at 5.0 and $D_{1.5}$ is at 7.5 (these now being values of HD). Then H, the severity of this quenching set-up, is $HD \div D$ or $5.0 \div 1.0$ or 5.0 (or $7.5 \div 1.5$ which gives the same result).

easiest and quickest method for the information gained. It involves cooling a bar 1 in. in diameter and 3 in. long by spraying water on one face. The hardness is then measured along the bar from the water cooled face to the opposite face. The piece is so small that it can easily be heated in a container with cast iron chips to reduce scaling, and since water cooling is used scaling is not so important. Furthermore, a very uniform cooling rate is obtained at the water cooled face so that reproducibility is good. This test is well suited for alloy steels and for deep hardening steels. For shallow hardening steels the so-called "L" bar is used with cupped end ("L" indicating low hardenability). These two test bars are the only ones that can be used to measure the hardenability of carburizing steels in the carburized condition.

Other bar shapes and tests have been devised and are used for individual cases. It should be borne in mind that we are really concerned with cooling *rate*, so that any test will probably be satisfactory if it gives the cooling rates required for the condition being studied.

When examined critically each of the methods will be found to be better adapted for certain special applications than for others. The first thought in considering the test suitable for a given set of conditions is whether the steel is of the deep or shallow hardening grade. The second consideration will be the size of the pieces to be tested. If the piece is around 1 in. in diameter and the steel is a deep hardening grade, about the only test that can be used is the end cooling method. Immersion quenching a 1-in. round bar will harden it to the center, so no measure of hardenability will be possible. If the steel is available in sufficient size the method of the immersion quench followed by sectioning the bar can, of course, be used. If the steel is ½-in. round or smaller it can be tested by turning it to 0.208 in. and inserting in a standard bar for the end cooling test which has been center drilled $\frac{7}{32}$ in. in diameter to within $\frac{1}{32}$ in. of the water cooled face. The standard bar and the inserted sample are then heated to the proper temperature, cooled on the standard fixture and the insert removed and hardness measurements made along the bar, the same as with the standard 1-in. bar.

If the steel is of the shallow hardening type and 1 in. round or larger, the hardenability may be measured by the Burns, Moore and Archer S-A-C rating, the Shepherd P-F test, the end cooled method using the modified end ("L" bar), or the immersion quench and cross-section method. The method of Grossmann may be applied to either shallow or deep hardening steels, but it appears much better suited to the shallow or water hardening steels.



Carburizing Methods

By O. W. McMullan
Metallurgical Dept.
The Youngstown Sheet & Tube Co.

THE ECONOMIC EMPHASIS placed on both materials and methods during the past decade has demanded articles that give satisfactory performance for the least overall cost. The tendency to reduce costs by using cheaper steels has eliminated the factor of safety inherent in some of the higher alloy steels and has necessitated better methods and control of carburizing and heat treatment. Properties of some steels now used are quite sensitive to case depth and microstructure. The fact that, under these circumstances, various carburizing methods remain with us, indicates that all have certain fields of usefulness.

At present, the trend appears to be toward gas carburizing, especially in continuous cycles. Several reasons might be advanced for this. Interest in controlled atmospheres has no doubt carried over into gas carburizing, and vice versa, and has resulted in the development of better equipment. Natural gas is the most suitable medium for gas carburizing and it is more and more widely available. The process is cleaner, lends itself to production line installation, and saves inventory of compounds or salts. The development of fine-grained steels has led to an increasing amount of direct quenching for which the continuous gas carburizing process is especially suitable. Close control of the process is necessary, but with such

control it is possible to get good uniformity and produce a desired carbon content in the case.

Since carburizing is but one step of the case-hardening process, it cannot be considered completely apart from the equipment. This is especially true since some recent installations have been more-or-less automatic units to turn out work in the carburized, quenched, washed and drawn condition. Such casehardening equipment utilizes gas carburizing. In some installations, the carburizing chamber is refractory lined instead of being an alloy retort. In the former case, each burner is fired into an individual muffle. Rather than a reduction in the amount or cost of alloy, the advantage claimed is an aid to production since the time for changing a small muffle is much less than for a large retort; burner muffles (radiant tubes) can usually be changed over the week end.

Conventional pack carburizing continues in wide use. It is the most satisfactory method where lack of equipment and experienced supervision may more readily produce highly unsatisfactory work by other methods. It is the most flexible process for intermittent work, as far as furnace equipment is concerned in the small shop, since the same furnaces may be used for other work. Refinements of this method in the larger installations have not been lacking in both batch and continuous furnaces. One inherent difficulty in carburizing in large containers has been the variation in case depth due to variation in time at heat caused by the insulating effect of the compound; thin walled containers, conforming to the shape of the piece carburized and containing much less compound, have provided satisfactory solutions of this difficulty in some cases. For certain types of work at least, the pack method presents more difficulties in direct quenching than does gas carburizing. Some of these difficulties are in removing work from containers, cleaning work before die quenching, and maintaining all the work from one container at a constant temperature until quenched.

Oil is successfully used for carburizing in smaller batch type furnaces. Two essentials for uniform carburizing by any method are the maintenance of relatively clean surfaces (free from coke deposit) and good circulation of active carburizing gases over all surfaces. Forced circulation of the vaporized oils makes this method especially suitable for basket loads, or for racks of many small pieces closely spaced.

The old cyanide baths have been often modified, usually with the idea of getting deeper cases in shorter time. (While nitrogen is added to the case as well as carbon, the baths are commonly held at higher temperatures where carbon penetration predominates, hence the process may be considered as a carburizing method.) Work produced might be divided into two chief classes. One is usually of low carbon steel where the requirement is to resist wear on small parts or where unit pressures are low. The other is to produce a highly wear resistant skin on a medium carbon steel, wherein the hardened core provides support for high unit loads. The most prominent application of the latter is for gears; it usually involves a minimum of heating time and produces a superficial hardness rather than a controlled case depth. Special baths have been developed for intermediate case depths, 0.010 to 0.030 in.

Attempts have recently been made to substitute other methods for molten bath carburizing. One of these is low temperature gas carburizing followed by a direct quench. The tendency for a high carbon surface layer to form at low temperatures brings about the possibility of a file soft skin ("friable" would probably be a better term than "soft"), especially on steels containing chromium which are subject to carbide concentrations on the surface. Dry cyaniding, or heating in gases containing both carbon and nitrogen with ammonia as the source of nitrogen, is said to give better fatigue life than molten bath cyaniding, but further data are needed to confirm those results.

The carburizing process takes place in two stages: (1) A chemical reaction which supplies carbon in an active form at the surface of the steel and (2) physical diffusion of the carbon to the required case depth. With relatively clean surfaces and good gas circulation, carbon

can be supplied to the surface faster than it will diffuse. Diffusion depends on time, temperature and steel composition. Future developments in any of the methods, therefore, may be expected along the lines of reducing heating up time (keeping down the gross weight of boxes, trays and volume of compound), and in equipment and handling methods. Probable developments in continuous cycles, including heat treatment where direct quenching is used, appear to be of a mechanical rather than a metallurgical nature. Steels of higher alloy content, however, retain too much austenite on direct quenching and do not develop the best surface structure and physical properties. Recent tests have indicated that good properties and structures can be developed in such steels by cooling to some intermediate temperature before reheating to quench, thus saving time and reheating costs over those required in reheating from nearer room temperature.

Flame Hardening

By John J. Crowe
Assistant to Vice-President
Air Reduction Co.

FROM A FAD which swept across the country a few years ago, flame hardening has now found its niche and is firmly entrenched as an economical method of heat treating, applicable to parts which because of size, shape, or other restriction cannot be readily hardened by the older conventional furnace methods.

Experience with many differing applications of flame hardening has resulted in a standardization of apparatus. There are now available, as standard equipment, torches and tips for many sizes of gear teeth up to 1 diametral pitch, for flat surfaces up to 12 in. or more in width and for both external and internal rounds up to approximately 12 in. in diameter. Equipment for larger sizes can be manufactured in a relatively short time.

This standardization of apparatus has eliminated the long delays incident to obtaining custom built equipment. The latter is now required only for special applications, such as automatic hardening machines or for unusual shapes.

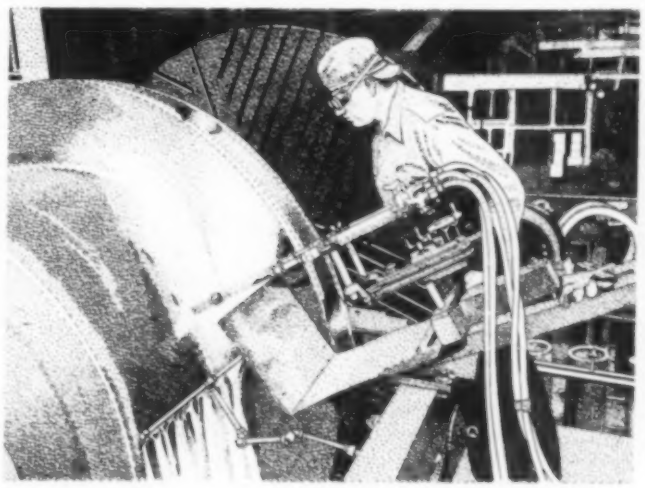
Flame hardening of the larger sizes of gears has, from the beginning of the revival of the process, constituted a major use, but lately the hardening of bearing surfaces on shafts, crankshafts, and cams has been going forward at such a rapid rate that it may soon exceed the tonnage of gears so hardened.

In the rapidly expanding machine tool industry, the importance of hardening the cast iron surfaces subject to wear — such as ways on lathe beds — has long been recognized. As the only practical method of accomplishing this is by flame hardening there has been a decided increase in this practice. Also in this same industry the use of the process has been extended to other parts, such as feed screws, cams, and similar parts which are not made of cast iron. As a result of several painstaking investigations by metallurgists in the machine tool industry, flame hardening is rapidly evolving from an uncertain art and is becoming a science in which the hardness and depth of hardness for various compositions are accurately predictable.

Localized hardening of wearing surfaces on parts made of malleable iron, by means of the oxy-acetylene flame, is readily accomplished and because of the increasing use of malleable iron in the automotive industry this application may soon assume a place of major importance.

Many of the wearing parts of the army tanks being manufactured in connection with the national defense program, such as sprocket wheels, are now being flame hardened. Laboratory experiments indicate favorable probabilities of extending flame hardening to materials classified as ordnance.

While some carburizing and hardening of the lower carbon steels is being done with a flame operated with an excess of acetylene, the possibilities in this field, like that of the field of flame softening, have not as yet been fully explored.



Hardness Conversion for Hardened Steels

By Howard Scott and T. H. Gray, Westinghouse Electric & Mfg. Co.

Diamond Pyramid Hardness 50-kg. Load	Rockwell Hardness: C-Scale-150 kg. Brale Penetrator	Rockwell Hardness: A-Scale-60 kg. Brale Penetrator	Rockwell Hardness: Superficial (From Wilson Mechanical Instrument Co. Chart No. 38): 15-N Scale	30-N Scale	45-N Scale	Scleroscope Hardness	Monotron Load Scale Value (19 Divisions)	Brinell Hardness 10-mm. Ball, 3000-kg. Load: Tungsten Carbide Ball: Hardness Number	Tungsten Carbide Ball: Diameter in mm.	Hultgren Ball DPN 940: Hardness Number	Hultgren Ball DPN 940: Diameter in mm.	Steel Ball DPN 900 (From A.S.M. Metals Handbook, 1939 Ed., p. 113): Hardness Number	Steel Ball DPN 900 (From A.S.M. Metals Handbook, 1939 Ed., p. 113): Diameter in mm.	Approximate Tensile Strength of Steel
DPH	R_C	R_A	15-N	30-N	45-N	Scl.	Mon.	BHN	mm.	BHN	mm.	BHN	mm.	T.S. x 10^3
250	20	58	68	42	20	32	26	192	4.35	207	4.20	201	4.25	100
		60	70	44		34	28	197	4.30	217	4.10	207	4.20	
	25	62	72	46	24	36	30	202	4.25	229	4.00	212	4.15	
				48	26	38	32	207	4.20	241	3.90	217	4.10	
300	30	64	74	50	28	40	34	212	4.15	255	3.80	223	4.05	110
	32	66	76	52	30	42	36	217	4.10	269	3.70	229	4.00	
	34	67	77	54	32	44	38	223	4.05	285	3.60	235	3.95	
350	36	68	78	56	34	46	40	229	4.00	302	3.50	241	3.90	120
	38	69	79		36	48	42	235	3.95	321	3.40	248	3.85	
	40	70	80	58	38	50	44	241	3.90	341	3.30	255	3.80	
400	42	71	81	60	40	52	46	248	3.85	363	3.20	262	3.75	130
	44	72	82	62	42	54	48	255	3.80	375	3.15	269	3.70	
		73	83	64	44	56	50	262	3.75	388	3.10	277	3.65	
450	46	74	84	65	46	58	52	269	3.70	401	3.05	285	3.60	140
	48	75		66	48	60	54	277	3.65	415	3.00	293	3.55	
500	50	76	85	67	50	62	56	285	3.60	429	2.95	302	3.50	150
			86	68	51	64	58	293	3.55	444	2.90	311	3.45	
550	52	77		69	52	66	60	302	3.50	461	2.85	321	3.40	
	54	78	87	70	53	68	62	311	3.45	477	2.80	331	3.35	160
600	56	79	88	71	54	70	64	321	3.40	495	2.75	341	3.30	
				72	55	72	66	331	3.35	514	2.70	352	3.25	170
650	58	80	89	73	56	74	68	341	3.30	534	2.65	363	3.20	
	60	81	90	74	57	76	70	352	3.25	555	2.60	375	3.15	180
700	61	82	90.5	75	58	78	72	363	3.20	578	2.55	388	3.10	
	62		91	76	59	80	74	375	3.15	603	2.50	401	3.05	190
750	63	83	91.5	77	60	82	76	388	3.10			415	3.00	
	64	83.5	92	78	61	84	78	401	3.05			429	2.95	200
800	65	84		79	62	86	80	415	3.00			444	2.90	
	66	84.5	92.5	80	63	88	82	429	2.95			461	2.85	210
850	67	85	93	81	64	90	84	444	2.90			477	2.80	
	68	85.5		82	65	92	86	461	2.85			495	2.75	220
900	69	86	93.5	83	66	94	88	477	2.80			514	2.70	
	70	86.5	94	84	67	96	90	495	2.75			534	2.65	230
950	70.5			84.5	68	98	92	514	2.70			555	2.60	
				85	69	100	94	534	2.65			578	2.55	240
1000				85.5	70	102	96	555	2.60			603	2.50	
				86	71	104	98	575	2.55					250
					72	106	100	598	2.50					
					73	108	102	623	2.45					260
					74	110	104	650	2.40					
					75	112	106	678	2.35					270
					76	114	108	708	2.30					
					77	116	110	740	2.25					280
					78		112							
					79		114							290
					80		116							
					81									300
					82									
					83									310
					84									
					85									320
					86									

Thickness of Stock Required for Accuracy
(Ten Times the Depth of Impression in Inches)

DPH	DPH (10 kg)	DPH (50 kg)	R_C	15-N	45-N	BHN
200	0.017	0.038	0.072	0.015	0.040	0.186
300	0.014	0.031	0.059	0.012	0.032	0.135
400	0.012	0.027	0.050	0.009	0.026	0.098
500	0.011	0.024	0.044	0.007	0.022	0.080
600	0.010	0.022	0.038	0.006	0.018	0.068
700	0.0092	0.020	0.033	0.005	0.016	—
800	0.0086	0.019	0.030	0.004	0.013	—
900	0.0081	0.018	0.027	0.003	0.012	—
1000	0.0076	0.017	0.025	0.003	0.010	—

Monotron tests at all hardnesses can be made on 0.018-in. stock. Scleroscope numbers vary with size; relations given are for 1-in. pieces.

In operating any test machine, follow manufacturer's instructions and check frequently against test blocks. Major causes of discrepancy: *(a)* decarburized skin, *(b)* specimens too thin, *(c)* off-standard indenters, *(d)* inaccuracy of machine.

Above conversions are for steel, irrespective of composition and structure, up to its maximum hardness, and for any other material having about 30,000,000 psi. elastic modulus, uniform in depth to bottom of impression. (An exception is that Rockwell test values for shallow hardened steel may be 1 or 2 points higher than by conversion from DPH.) For sintered carbides (DPH 900 to 1700) with much higher modulus the relations between DPH and Rc may be computed from $DPH = \frac{2.445 \times 10^6}{(B - Rc)^2}$ wherein constant B is 118 for carbide (120 for steel).

Nitriding

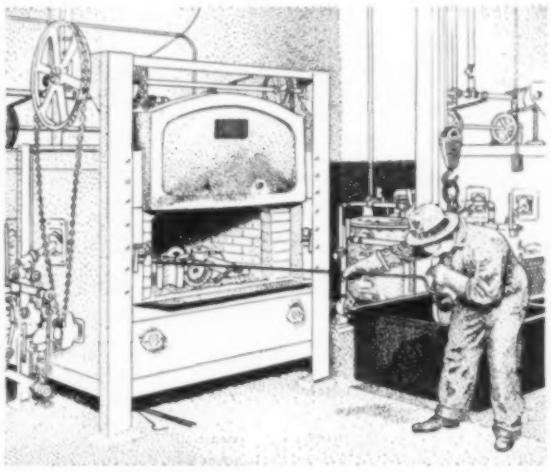
By Victor O. Homerberg
Professor of Metallurgy
Massachusetts Institute of Technology
Technical Director, The Nitralloy Corp.

THE PRESENT BIG DEMAND for aircraft engines has greatly increased the use of nitralloy and the nitriding process in the aircraft industry. One aircraft engine manufacturer uses this steel for several hundred parts, one of the most important of which is the cylinder barrel or sleeve.

In view of this increased demand, the possibility of decreasing the time of nitriding to procure satisfactory results has become a desirable problem for investigation. Various cyclic treatments have been recommended and tried but without obtaining the anticipated results. This problem is being studied in detail and from preliminary results that have been obtained it is believed that it can be solved. A proper balance of times of exposure at the proper temperatures is being correlated with the rates of diffusion at these temperatures. Since the mechanism of nitrogen hardening is quite well understood, it should be possible to procure diffusion without sufficient agglomeration of the nitrides to soften the part.

In nitriding, a thin white layer containing over 10% nitrogen is procured on the surface. This layer is somewhat brittle and is not so hard as the case immediately underneath where the nitrogen content is about 3%. Prevention of this white layer is therefore desirable, in order to procure a hard case with maximum toughness. This represents another problem that is being investigated. The extensive research program that is now being conducted at Massachusetts Institute of Technology promises to give results of great value.

The textile machinery field represents a potential big user of nitriding steels and the nitriding process. Introduction of new textile fibers, and operation of the machines at increased speeds, require better wear resisting materials. Instead of a nitriding temperature of 975° F., which is most commonly used, a temperature of about 940° F. is required to produce the best hardness. Also, the steel used by the aircraft companies should be employed for most textile machinery applications for best results. This steel contains approximately 0.40% carbon, 1.60% chromium, 1.25% aluminum and 0.40% molybdenum.



Heat Treatment of Cast Irons

By Garnet P. Phillips
Chief Metallurgist, Automotive Foundry Division
International Harvester Co.

HEAT TREATMENT of cast iron, other than malleable, is such a large subject that one can only note a few items in small space. Diverse as are the possibilities it must be admitted that most iron foundries do not as yet practice the art.

Heat treatment for relief of internal strain of gray iron castings is done more generally, particularly to castings subjected to varying temperatures in service. While such heat treatment has been common practice for years on certain castings, its extension to others used in automotive service is increasing due to the increased power output of engines with increasing amount of heat generated.

Hardening of castings is a field where a variety of techniques are possible. The use of conventional oil quenching and drawing continues with a widening field of application. Flame hardening, particularly on heavy sectioned castings, is being used and will probably be used more extensively, although variable results and surface checks are not rare. Nitrogen hardening is not done very often on cast irons, probably due to difficulties encountered in obtaining sound castings of the necessary alloy compositions. The recent introduction of induction hardening of gray iron castings with high frequency electrical currents may be widely extended, particularly to engine cylinder sleeves and liners. More and more hot quenching is being done on suitable thin sectioned castings where maximum hardness and toughness are desired; as experience is

gained the process will probably be more widely used and lead to further research on metal compositions best suited to its application. Air hardening of suitable and fairly highly alloyed irons continues to be done in a rather limited way on castings where the cost of the alloy is justified by the otherwise fairly low cost heat treatment.

Annealing of gray iron castings for softening and frequently for both softening and stress relief continues in use in somewhat increasing volume. Practically all castings that are to be machined and hardened are first given either a stress relief heat treatment or an anneal prior to machining. In addition numerous castings which are not required to have wear resistance are annealed to obtain maximum machinability.

In general the hardening of castings for increased wear resistance is the field receiving the major share of attention and study, due to the increasingly severe service requirements of first-grade gray irons.

Rubber Coatings on Metals

By H. E. Cook
General Supt. of Engineering
The B. F. Goodrich Co.

WITH the countless new developments and increased knowledge of stainless steels and the numerous non-ferrous, corrosion resistant alloys, many development, production and maintenance men now think only in terms of metals when problems of corrosion or abrasion confront them. However, there is another material, rubber, which when properly applied to the production problem in hand may give a far longer life at lower original cost and maintenance. Its application to industrial production, when bonded with and vulcanized to metal parts, has been accomplished only since 1924. It was then that the process known as "Vulcalock" was developed by chemists of The B. F. Goodrich Co. Today few of the chemical or processing industries but have successfully used rubber covered parts to overcome corrosion or abrasion problems or combinations of both.

Just as it is true that there is not any one stainless steel or alloy or metal coating which will be suitable for all uses, so too is it true that there is no one rubber compound which will fit all the needs of industry. It is safe to say that no two installation problems are alike. However, when the conditions of service are accurately known by the manufacturer, vulcanized rubber can be compounded to resist actual immersion for long periods in any of the inorganic acids (except those of strongly oxidizing character). The same is true of nearly all inorganic salts and alkalies, and to a somewhat more limited extent of commercial organic materials. The development of synthetic rubbers, with their modified properties, is also somewhat broadening the field of use.

Unlike metals, properly compounded rubber linings do not dissolve in the common corrosive chemicals but may gradually deteriorate by age, heat and chemical reaction. They last almost indefinitely unless physically abused.

Rubber does not possess the physical strength to be used structurally; ordinarily parts are first made from metals and then covered with the properly compounded rubber. However, some hard rubber parts such as pipe and rods may be made entirely of rubber when they will be only lightly stressed.

Rubber linings can be and have been successfully bonded to many different structural materials. There are few cases, however, in which mild steel is not the logical choice because of its low cost, ease of fabrication, strength and rigidity, its adaptability to a wide variety of structural and process requirements and its easy repair. If one must bond rubber to alloys other than steel, the manufacturer should be consulted, as there are some limitations; alloys of high copper, lead, manganese or silicon content are generally to be avoided.

Rubber coatings may be applied by the anode process, the Vulcalock process, by spraying, or the brass plating method which involves mold curing. When large production of small parts is contemplated the anode process is usually the one preferred, but when tanks or large objects are covered the "hand Vulcalock" method is used. In this a sticky, unvulcanized sheet is pressed down by hand on a sand blasted and cemented steel surface and the completely covered article vulcanized. Both processes have been highly successful and adhesions exceeding 500 psi. are obtained. Coatings are usually applied by the manufacturer in his own plant but they have been applied and vulcanized at customers' plants. Damaged linings may be successfully repaired in the field.

A few of the successful applications are tank cars, storage and pressure tanks, pipe and fittings, fan housings and blades, agitators, pumps, rubber tracks for tractors, motor mount-

ings, bumper blocks, vibration dampeners, and water lubricated bearings for boat propellers. Hydrochloric acid and numerous chlorides are most difficult to handle in bare metal containers, yet rubber lined equipment is very successful. Other interesting uses are for pickling and plating tanks, fume ducts, leaching and evaporating equipment. Ash handling equipment is rubber coated for its combined resistance to acid and scour.

Plating of Aircraft Parts

By George E. Stoll
Chief Chemist & Metallurgist
Bendix Products Division, Bendix Aviation Corp.

CHROMIUM is popularly thought of as the bright final plating on metals for protection and decoration. Not as well known is its functional use in the landing gear of airplanes.

There are parts on the very important landing gear that require protection from corrosion and wear resistance. These parts are made of S.A.E. 4135 steel, heat treated to Rockwell C-39 to 42, having a tensile strength of 180,000 to 200,000 psi. and an elongation of 13% in 2 in. This hardness is not sufficient to withstand the wear encountered, and if the steel is heat treated to a higher hardness, the impact values will be reduced too much. Plating these parts with 0.003 to 0.005 in. of chromium gives the corrosion protection and the hard surface needed for the functioning of these parts.

The technique required for this type of work is different from the usual decoration job which is usually a triple plate. The chromium is deposited directly on the cleaned steel parts at a higher current density and at least 100 times as thick.

Bright zinc plating has received considerable publicity in the past few years but very little has been published on the advantages of a chromate dip for these zinc plated parts. This process consists of plating the steel parts in conventional zinc cyanide solution, followed by a rinse. The parts are then dipped in a solution of sodium dichromate, sulphuric acid and water.

This process was introduced by TRUESDALE and WILHELM of the New Jersey Zinc Co. and materially improves the corrosion resistance of the zinc plate. The dip forms a visible film on the zinc, a greenish brown color tending to display iridescence. It will increase the salt spray resistance by more than 50%.

Bright Plating

By F. F. Oplinger
Assistant Manager, Electroplating Division
E. I. du Pont de Nemours & Co.

BRIGHT DEPOSITS from electroplating solutions have made a great deal of progress as a production tool during the last decade. So-called bright deposits have been obtained for many years, but they were limited to very light weight coatings and to only a few of the metals commonly plated. Now most of the common metals—cadmium, zinc, copper, nickel, chromium and silver—are being electrodeposited in a bright lustrous condition to almost any normally desired thickness on various types of base metal. To the average well-informed plater, the production of bright deposits is no longer a mystery and he is familiar with the various means for securing them. It is a requirement of his job.

Bright deposits are produced from most plating solutions principally through the use of organic materials. Formerly, improved results in plating baths were obtained by the help of complex materials whose composition and structure were mainly conjectural. Control was generally difficult and frequently impossible. Modern methods now call for the use of well-defined organic chemicals whose formulas and constitution as well as physical properties are definitely known and many of which can be regulated accurately by means of chemical analysis.

Impurities in plating baths, whether organic or inorganic, must also be carefully controlled. Definite evidence shows deleterious effects of impurities present in amounts as small as two or three parts per million. Organic material may have a very beneficial effect when present in one part per million or even less.

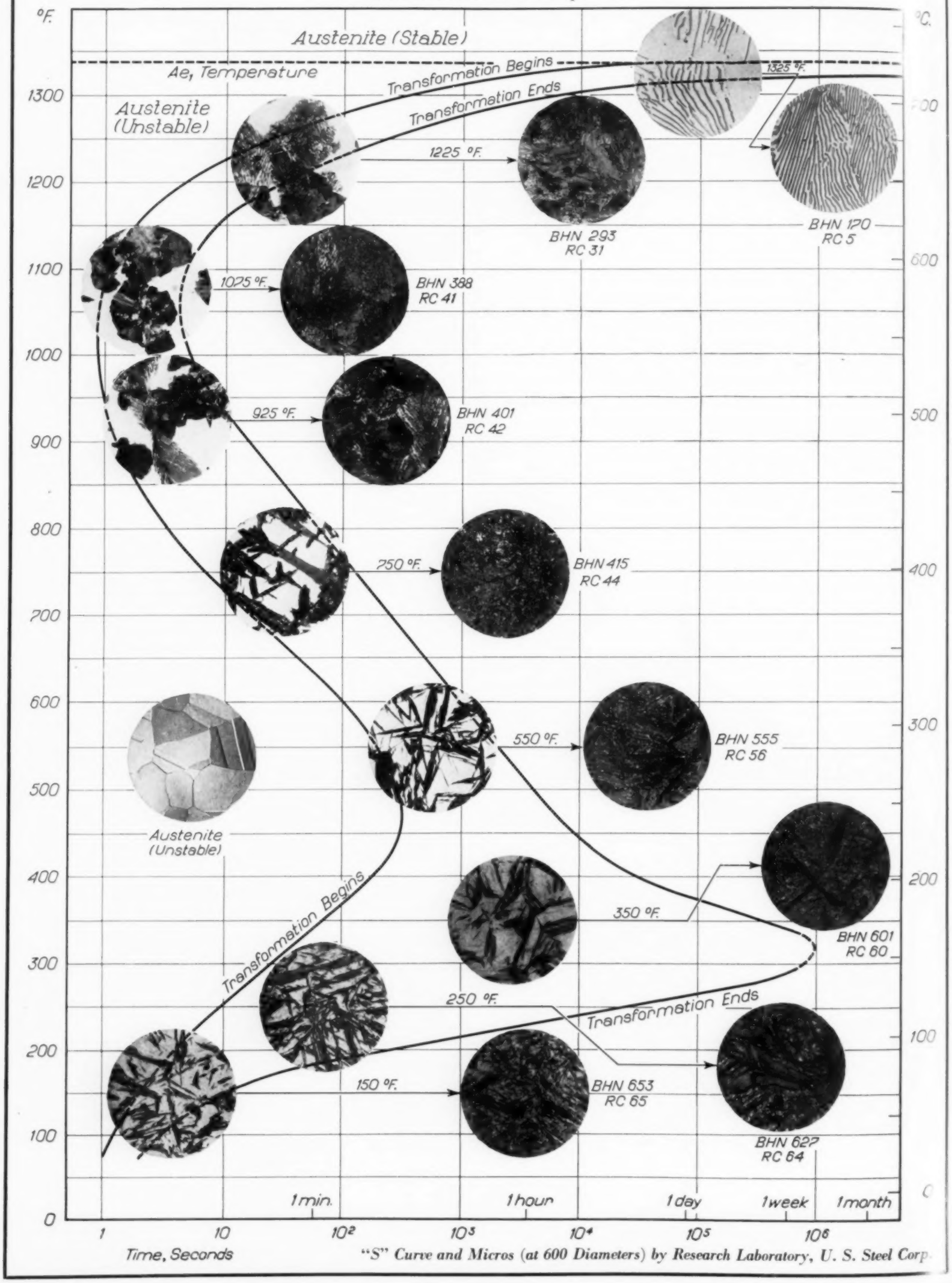
Truly it can be said that the production of bright coatings has caused electroplating to be placed in the category of an exact science.

The cost per pound of various organic brighteners is frequently quite high, but this is usually offset by the fact that a small amount goes a long way so that the gain from using the brightener is generally far greater than the added cost of using it.

Nickel Plating—The outstanding example of the importance of bright deposits is in the field of bright nickel plating. Almost unheard of only a few years ago, at present a major percentage of nickel plating is done in bright plating baths. Great economies *(Turn to page 434)*

Transformation of Austenite in 0.78% Carbon Steel

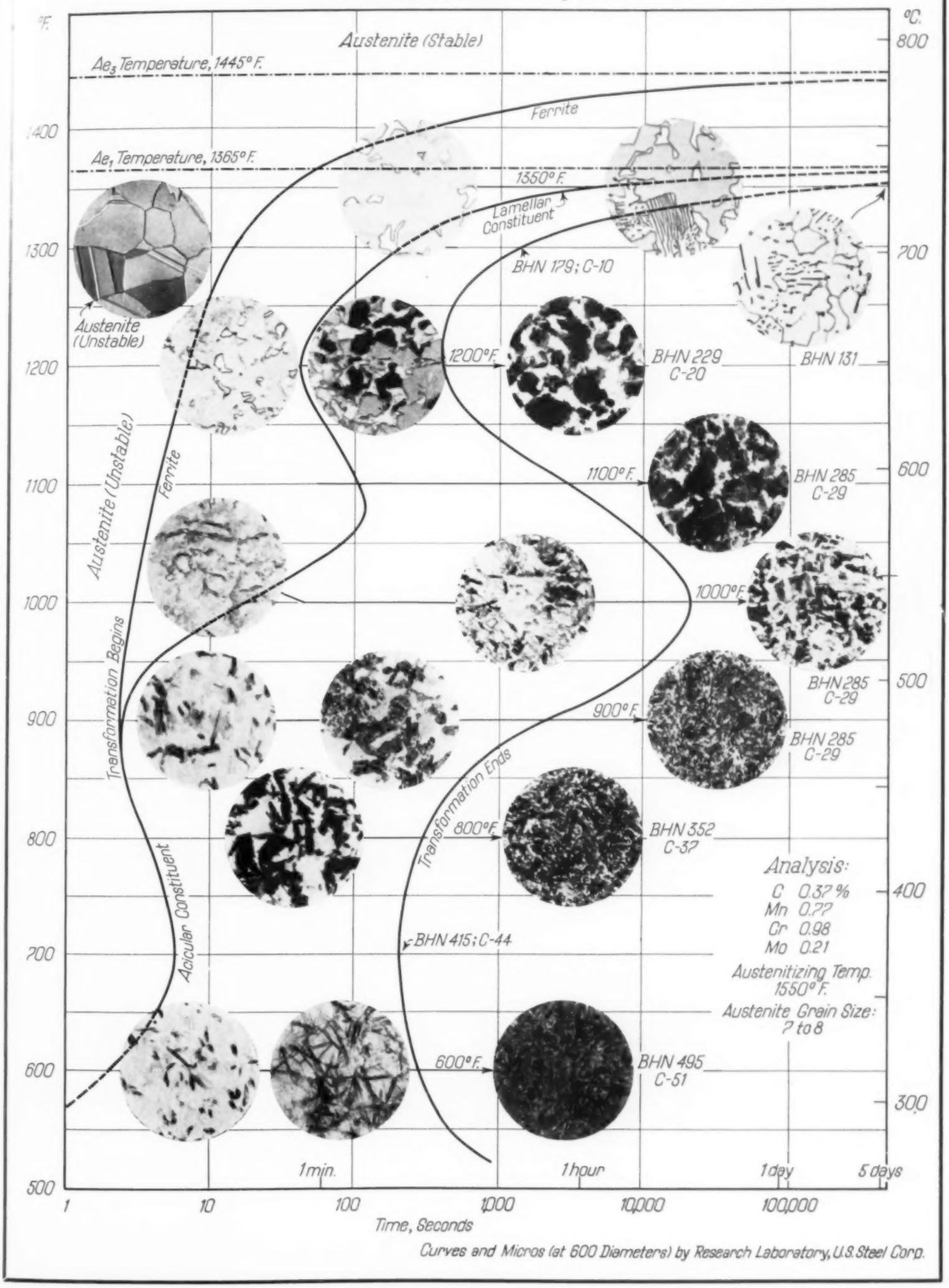
at Constant Sub-Critical Temperature



"S" Curve and Micros (at 600 Diameters) by Research Laboratory, U. S. Steel Corp.

Transformation of Austenite in 4140 Alloy Steel

at Constant Sub-Critical Temperature



Curves and Micros (at 600 Diameters) by Research Laboratory, U.S. Steel Corp.

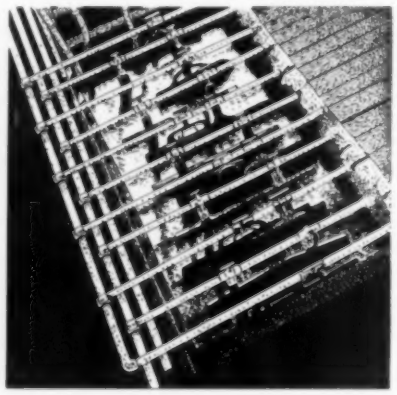
have been effected through the elimination of polishing and buffing. Heavier and more uniform deposits are being produced. Thus, articles with intricate shapes and designs are now frequently plated at lower cost and in a far more satisfactory manner than was previously possible.

Well-defined organic chemicals are widely used to produce these effects, definitely controlled through chemical analysis.

Cadmium Plating — Cadmium plating has been used on a large commercial scale, particularly during the last 15 years. It was not long after its introduction that bright coatings were produced commercially by means of a variety of organic materials. Frequently, also, the bright deposits so obtained are further improved by "bright dipping", which consists of brief immersion in dilute solutions of oxidizing acids.

Deposits of cadmium from solutions containing brighteners usually have a finer grain structure than dull matte deposits, but the main benefit comes through greatly improved appearance and tarnish resisting qualities, so that bright cadmium deposits are now widely used for decorative purposes.

While considerable progress has been made in the last few years on new brighteners for cadmium plating, the most important improvements have been made in the methods of using them, based on the fact that a definite relationship exists between sodium cyanide and brightener consumption. Brighteners are usually of a complex nature and are not generally determined directly by chemical analysis. The average plater, however, produces excellent and consistent results over long periods of time.



Zinc Plating — Up to very recently almost all zinc deposits were dull matte and frequently very unattractive. Purification of solutions led to the discovery of suitable brightening agents. Bright zinc solutions are very simple to control, now that the basic principles are understood. Zinc continues to be mainly a rust-proofing rather than a decorative metal, and appearance so far as brightness is concerned is often wholly unimportant. However, when low cost decorative and rust-proof coatings are required, bright zinc coatings are extremely useful. They are produced directly from the bath, as is the case with cadmium. Dilute solutions of oxidizing acids also are used to improve luster and increase tarnish resistance.

Another importance of bright zinc plating is that, prior to its advent, the composition of solutions in many plants varied quite widely. Bright zinc plating clarified this situation so that solution, composition and control methods in many plants over widely scattered areas are now virtually the same.

Copper Plating — Bright copper deposits (very light weight flash coatings) have been produced for many years. Only recently has it been possible to brighten heavy coatings, mainly through improved technique involving constant temperature control, uniform solution agitation and organic and inorganic addition agents.

Bright copper plating is also important because the uniformity and luster of subsequent bright nickel deposits is improved. A great many ills common to copper plating, such as anode insulation, cyanide decomposition and high cost, have been greatly minimized or eliminated.

Silver Plating — Silver plating practice has not varied much for a long term of years. Analytical and control methods have not varied greatly in the last decade. Semi-bright deposits by means of organic addition agents have been produced for many years under conditions generally well known.

The importance of bright coatings is mainly in the ease of buffing. Very light buffing with consequent low metal loss produces the high finish required on silverware.

Chromium Plating — Chromium plating, since its introduction a few years ago, has commonly been done bright. Dull deposits can be produced but are not widely used. Chromium is mainly used for decorative purposes although there is considerable "hard chromium" deposited on tools and dies for wear resistance.

This section of our subject is of interest in another way, because the advent of bright chromium plating aroused great interest among platers and chemists. It is largely responsible for subsequent production of bright coatings of the other metals and improvements in methods of chemical control of plating operations.

Developments in Surface Finish

By John M. S. Hutchinson
Production Research Division, Chrysler Corp.
and John M. Lessells
Massachusetts Institute of Technology

THE PROBLEMS involved in the study of surfaces are of a very fundamental nature. The phenomena of friction, corrosion and the behavior of lubricants are far from being explained theoretically. For the past few years these problems have received attention in all parts of the world from both theoretical and practical viewpoints. From the latter viewpoint surface problems may be classified as pertaining to sliding surfaces, static surfaces or corrosion resistant surfaces.

Superfinish and Co-Directional Finish — Reduction of friction and wear have been recently accomplished by several interesting developments to which the Chrysler Corp. has contributed much. This process known as "superfinishing" has made engineers conscious of the importance of surface in obtaining greater load bearing capacity. Improvement in the surface by increasing the actual area of contact also greatly improves the frictional heat transfer and dissipation. From this has developed the common engineering practice to finish-machine parts in the final operation by honing in a direction which they will eventually work. For example, aero-engine cylinder bores obtain, in the last phases of bore finish, a certain number of strokes in an axial direction. Hence has developed our present habit of speaking of "controlled finish".

Plating of Bearing Surfaces — Probably the best class of materials developed to date for aero-engine main bearings are of the copper-lead type containing small percentages of either silver or tin as alloying elements. It is generally accepted that their performance is much improved by coating with either lead or indium, or lead and tin. New X-ray tubes with rotating target use a film of barium, vaporized on the steel ball bearings, as a "lubricant". The underlying reasons for these very definite advantages are not clearly understood, but there is no doubt these benefits are all associated with surface phenomena.

Plating of Fitted Surfaces — The recent work of Gough and others has shown us that in the case of closely fitting surfaces, such as press fits, a form of corrosion called "frettage corrosion" is always liable to develop and is independent of the materials used. Its cause is not yet clearly understood, but it also is definitely a surface phenomenon. It is liable to occur in all classes of machine parts where press fits are adopted. In ball or roller bearing applications some benefits are obtained by copper plating the mating surfaces (which again emphasizes the importance of the surface).

Effect of Finish on Fatigue Strength — It is generally understood that the fatigue strength of machined parts depend on the degree of surface finish. It is therefore to be expected that the improved finish obtained by "superfinishing" must add to the strength of a machine parts when subjected to cyclic stresses.

Shot Blasting and Roller Burnishing are comparatively new developments whereby the surface layers are subjected to a definite amount of cold work. The mechanism is not clearly understood but increased fatigue strength must be due to a favorable residual stress resulting from the shot blasting. In this case the surface is actually more rough than prior to treatment but the strength is greatly increased; in the case of coil springs this increase, as measured by stress range, may be as high as 100%. Roller burnishing of such inner surfaces as the diamond-bored barrel of a gray iron shock absorber cylinder is done by pressing the piece over a set of rapidly rotating rollers that increase the internal diameter about 0.001 in.

Electrolytic Etching — Smooth surfaces can be produced by electrolytic etching or "de-plating". This method is still being developed, but more will undoubtedly be heard of its uses.

Phosphorus Compounds — Another recent development makes use of a phosphorus compound which forms iron phosphide with the hot iron at points of metallic contact. The iron phosphide alloys with the iron, reducing the melting point. The asperities can then melt locally without causing general scoring of the mating surfaces. This is probably akin to the action of the extreme pressure lubricants; by action of the oil the metallic surfaces are protected against scoring and can thereby sustain greater loads without damage than with ordinary lubricants.

Other Methods — These can be mentioned as Parkerizing and Bonderizing, and involve chemical coatings on the rubbing surfaces. These coatings minimize the scoring and wear in the event of oil film rupture.

TO THE steel treater who appreciates the importance of using high quality chemicals of dependable uniformity, du Pont products offer worthwhile advantages. They help to maintain manufacturing schedules along predetermined lines of quality and cost.

Each du Pont chemical is manufactured carefully to meet the requirements, to give the expected results in service. Manufacture is supported by a program of research and product development—to produce continuous improvement in quality, to lower the cost of the chemical and to produce better products for new requirements of the industry.

With these products made under strict chemical control, production is made easier and more economical. And for their useful application, du Pont offers the skillful assistance of experienced metallurgists.

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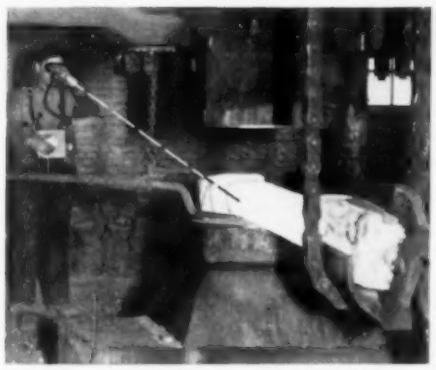
Production Aids FOR BUSY MEN & MACHINES

Described here are a few of the hundreds of ways in which L&N instruments and furnaces can help the metal-making and metal-using industries to step up their production. If you see anything that interests you, send for its catalog; if you think we can help in some way not mentioned, give us details and we'll cooperate fully. Instruments are helping many a plant to climb an unaccustomed peak in production.

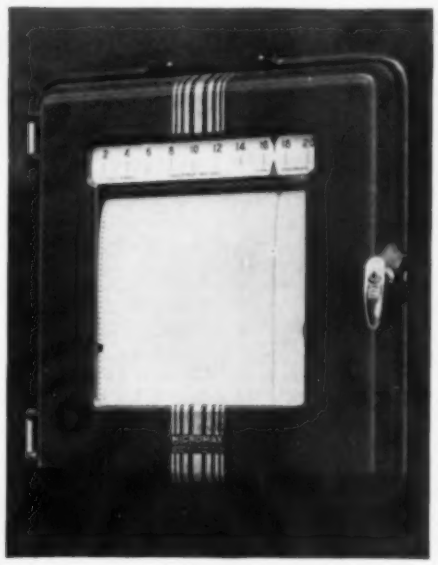
Parts for pumping engines are here being Homo-tempered with extreme uniformity in the new heat-treat department of Hale Fire Pump Co., Conshohocken, Pa.

Parts tempering in mass-production lots is one of the processes which may sound easy and actually be difficult. If you find it so, why not turn to Homo Tempering Furnaces. They were the original forced-convection furnaces, and as made today they have but one purpose — to temper on a strictly non-rejection basis, regardless of how rigid the quality standards may be. See Catalog T-625, or send for an L&N engineer.



Unnecessary re-anneals and even rejects of forgings are more easily prevented when press operator checks temperature with L&N Optical Pyrometer

Forging temperatures, and tapping and pouring temperatures of furnaces, converters, cupolas, ladles, etc., are measured accurately and easily by the new (potentiometer-type) L&N Optical Pyrometer. See Catalog N-33D.



Control of a 3-zone wire-patenting furnace's temperature is maintained within straight-line limits by three Micromax Pyrometers, of which this is one

A quick way to improve the operation of almost any industrial furnace is to equip it with a Micromax pyrometer. The equipment suits big or small furnaces, continuous or box types, fired with any fuel or heated electrically.

The responsiveness of the Controller enables it to act more quickly and speedily than even the best operator can act; its dependability is outstanding. Every other factor in furnace operation has a better chance to reduce costs and increase production, when Micromax controls the temperature.

See Catalog N-00A, or, if you have a specific problem, ask for an L&N engineer.

Temperature in a checker chamber of an open-hearth is detected by this Rayotube. It is connected to a Round-Chart (Model R) Micromax Pyrometer

This unusual-looking thermocouple is a "Rayotube". It replaces a couple under certain conditions: (1) When furnace gases either corrode or "poison" a couple (*Examples:* brazing, smelting). (2) When temperature is so high that a couple is insensitive and couple maintenance objectionable (*Examples:* soaking, melting). (3) When object moves and a couple can't be used (*Example:* rolling). (4) When furnace rotates (*Examples:* heat-treating, calcining). (5) When temperature of the furnace charge rather than of furnace atmosphere, is to be measured (*Example:* parts hardening). (6) Where vibration breaks a couple (*Example:* forging).

To measure, record and control the temperature detected by Rayotube, one may use Micromax Strip-Chart Pyrometer, or Round-Chart Micromax, or Indicating Controlling Micromax, or Speedomax, or portable Indicator. See Catalog N-33B.

Draft in big furnaces is controlled with great sensitivity and responsiveness by the new L&N Furnace Pressure Controller. It can be applied to any controllable furnace, and tied in with complete combustion control if desired. See Catalog N-01A-600.

Blast furnaces are using a special Micromax Control which gives uniform-temperature hot blast and "tells all" about measuring the temperature in domes, downcomers, etc. See Catalog N-33A-642.

Jrl Ad ENT-0600C(4)

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LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

YOUR COMMERCIAL HEAT TREATING

GUIDE

One of these established companies is as conveniently available as your telephone. Let this expert solve those unusual heat treating problems—or call him in to do the complete job, including carburizing, cyanide hardening, nitriding, tool, die, high speed steel and high carbon chrome steel hardening.

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Commonwealth Industries
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American Metal Treatment Company
ELIZABETH 2-2121

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Wesley Steel Treating Company
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NEW YORK
Heinzelman's Heat Treating Hardening Wks., Inc.
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Metlab Co. (Metallurgical Laboratories, Inc.)
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Heat Treating Progress

ELECTRIC SALT BATH HIGH SPEED STEEL HARDENING

Electric salt bath high speed hardening probably deserves the caption "Heat Treating Progress" more accurately than any other relatively new heat treating development.

Anyone who has had either first hand or supervisory experience with the hardening of high speed steel by older methods knows the difficulties involved. In conventional open furnace equipment scale and pitting are practically inevitable. Sharp edges are rounded by incipient fusion, while decarburization is difficult to avoid with 18-4-1 steel, and quite impossible to eliminate on the cobalt and molybdenum analyses.

Certain newer furnaces with atmospheric control of various types unquestionably were a step in the right direction, especially with respect to surface finish. However, decarburization, that bad actor of the heat treating drama, was by no means completely tamed.

While it is perhaps dangerous to characterize anything in these fast moving times as the ultimate answer to troublesome problems, our own experience with commercial salt bath hardening of high speed steel would indicate that the advantages of the process can hardly be exaggerated. Irrespective of size, shape or analysis, we have yet to see a tool come through the salt bath treatment with rounded corners, scale, pits or the slightest trace of decarburization. We feel that results are, as a matter of conservative fact, as close to perfection as we are ever likely to find.

Operating costs, with volume production, are not excessive, but salt bath hardening of high speed steel is definitely not practical for the average plant because the equipment raises electrical demand charges very appreciably, and costs a lot of money to maintain in proper operating condition. Obviously pot and electrode life, at 2300° F. plus, is short, and replacement costs are high.

If you would like to see one of your high speed steel tools hardened by this new magic of American inventive genius send it to us for a demonstration. We promise a most pleasant surprise.

THE QUEEN CITY STEEL TREATING COMPANY
CINCINNATI, OHIO

Flame Hardening

• MAXIMUM HARDNESS
• MINIMUM DISTORTION

Nossir! Flame hardening is too crude for Cincinnati. This is a high quality heat treating town!

That's what we told the equipment salesmen years ago, but we were so utterly wrong we're almost ashamed to tell the story.

Actually, flame hardening is about the most valuable process that ever came into this plant.

Gears (spur, spiral, bevel, herringbone) of any size can be hardened without measurable distortion.

Solid rolls and shafts, 12″ in diameter, made of plain carbon steels, come out straight and as hard as if they were ½″ through.

Cast iron hubs and discs take on the hardness of tool steel—stay flat and round.

There's really no end to it! If ordinary heat treating warps your parts—doesn't get them hard—isn't worth a darn for any other reason—think of flame hardening—think of Queen City Steel Treating Co., and send us the job.

Of course we do every other type of heat treating in our modern plant. Let us work with you to solve your problems.

Rolls — S.A.E. 1045 — flame hardened on working surfaces and journals to 85 Shore, WITHOUT MEASURABLE DISTORTION

M.T.I.

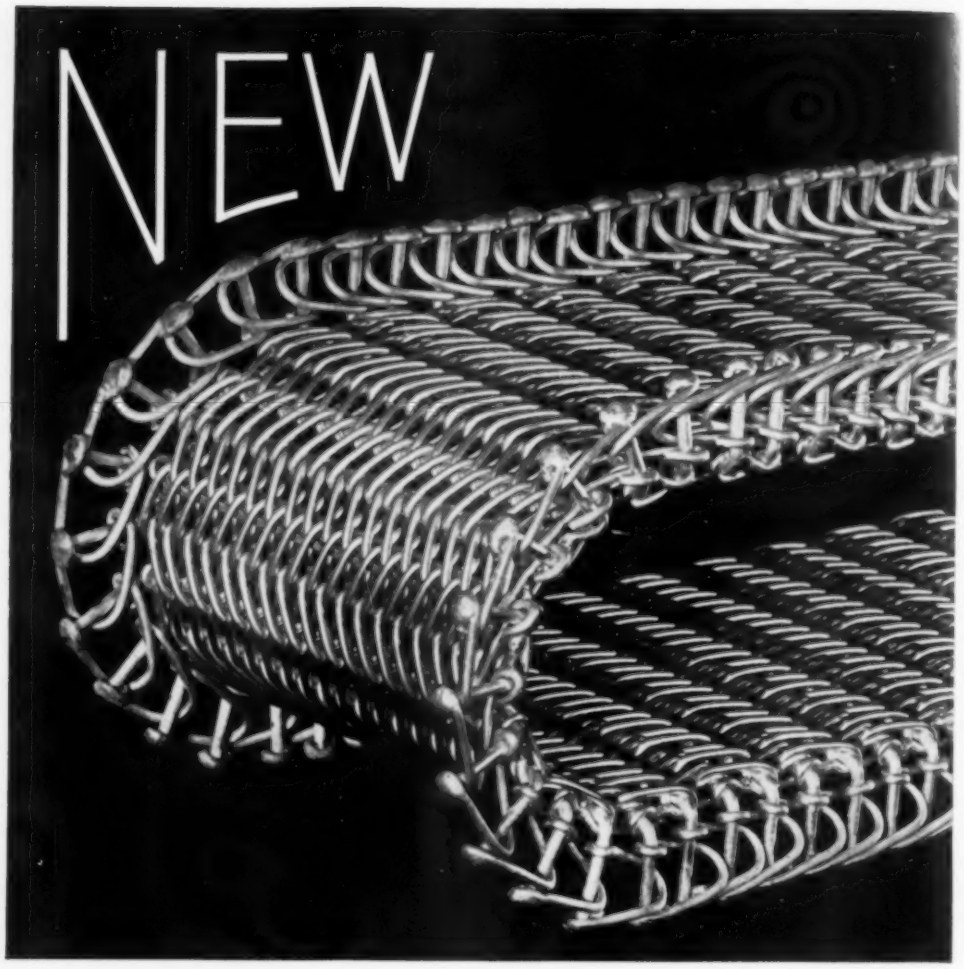
THE QUEEN CITY STEEL TREATING CO.
CINCINNATI, OHIO

METAL SHOW
Booth H-12

1937
Universal
Weave

1938
Cord Weave

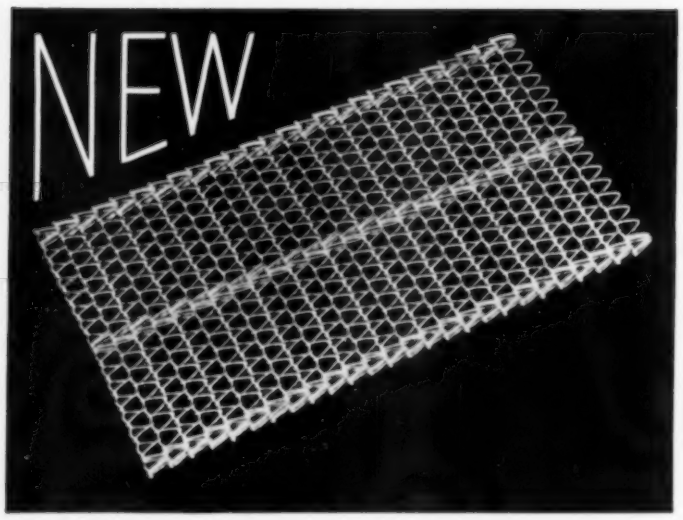
1939
Flanged Edge
on Cord Weave



1940
TELESCOPE EDGE

and

Chevron Reinforced Balanced Weave



Audubon has always had "something new" to announce at the Metal Show. This year is no exception, but instead of one, we have two new developments in Metalwove Belts. . . . The new Telescope Edge (Patent Pending) can be applied to any Rod Reinforced Belt. This retaining edge can be as high as 25% to 30% of the diameter of the smallest pulley over which the belt operates. . . . The Chevron Reinforced Balanced Weave (Patent Pending) provides additional strength and reduces stretch in this familiar weave. . . . Our engineers, located in most principal cities, will gladly recommend the correct Metalwove Belt for your requirements. Let us send you our 44-page catalog No. 50.

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WIRE CLOTH CORPORATION
Subsidiary of Manganese Steel Forge Co.
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SURFACE

By The Drever-Industrial Stainless Nitriding Process*. . . Nitrided stainless steel or stainless iron parts of any size give superior wear resistant properties and retain corrosion resistance . . . A tightly adhering glass hard (89-93 Rockwell 15N) abrasion resistant case.

HARDEN

AT THE
METAL SHOW
BOOTH Y-13

The surface hardened case (.002" to .028" thick) can be ground or polished without loss of abrasion resistance or loss of corrosion resistance . . . Descriptive literature on request . . . See what can now be done with Stainless. *Process and Equipment Patented.

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THE
DREVER-INDUSTRIAL
STAINLESS NITRIDING PROCESS

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749 E. Venango St., Philadelphia, Pa.

and looks to modern gas equipment to speed up production

The quickened pace of industry today has brought new demands for faster manufacturing processes . . . and Gas and Gas research have helped many plants to step up production, to maintain and improve quality, to attain greater precision in manufacture, and to cut over-all costs.

Whether for munitions orders or for household necessities, wherever delivery dates have become a nightmare to management, Gas engineering has pioneered to iron out production problems. Developments such as the luminous Gas flame, the Gas radiant tube heater, the Gas immersion heater, atmosphere units to use Gas as a chemical as well as for heating . . . all these achievements and many more are being swung into action as industries of all types mobilize for defense.

If production is being limited in your plant by slow-motion operations, investigate Gas and modern Gas equipment. Your Gas Company will be glad to show you how Gas can step up your own production and, if you wish, give you facts on how other companies in your line have used Gas equipment to solve specific problems in manufacturing.

AMERICAN GAS ASSOCIATION

INDUSTRIAL GAS SECTION . . 420

LEXINGTON AVE., NEW YORK CITY

Here's Proof

that gas speeds production, improves quality, cuts costs.

IN MAKING FINE SPRINGS

The advantages of heating metals by means of recirculated air with Gas fuel are becoming accepted more and more by industry. The Fort Pitt Spring Co., McKees Rocks, Pa., presents further evidence of the efficiency and other values of Gas in the tempering of metals within narrow ranges of temperatures. Recirculating the heated air and products of combustion results in high thermal efficiency and paves the way for higher production and greater uniformity.

GREATER OUTPUT IN LESS TIME—WITH GAS

Heat treating with Gas plays a very important role in the manufacture of sewing machines, as witnessed by the experience of the Free Sewing Machine Co., Rockford, Illinois.

Four years ago—with old-type equipment—it "took a full day to bring the oven furnace up to temperature and an even heat throughout the chamber was practically impossible." Since installing new Gas-fired equipment, it is possible to get two carburizing heats and one annealing in an eight-hour day and to double the loadings in each charge. Working space increased, working conditions better, plant kept very clean—a story, indeed, for Gas.

IN FACT, in hundreds of industries where quick, controllable heat is essential, and where economy is a "must," Gas and modern Gas-fired equipment are considered indispensable. And this goes for industry in peacetime, wartime, or any time. Wherever the need is for heat, Gas is the preferred fuel.

Visit the A.G.A. Combined Industrial Gas Exhibit, National Metal Exposition, Cleveland, Ohio Oct. 21-25, 1940.

BRING 'EM ON—
WE'RE READY!

Ready for metal working and heat treating problems which are bound to rise as industry swings into action to meet the urgent need for national defense.

Armament and munition making are not new to us. Houghton did a major job during the last World War along lines of carburizing, heat treating, machining, rust prevention.

That cumulative experience has led to our present processing products — modern . . . geared to today's production needs... aimed at the one objective of quality performance at lower cost per unit produced.

If you face new, unfamiliar problems relating to the materials listed on this page, feel free to lay them before us. Call on the Houghton Man, or write, wire or phone:

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VISIT US AT BOOTH B-4
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CUTTING OILS

Soluble or straight oils and bases that assure finer finish, longer tool life, fewer rejects, speedier production.

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No. 2 Soluble—the standard for 25 years—still the leader for uniform depth of hardness and length of service.

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A new, proven line-up for every type of drawing operation: shells, cartridge cases, automotive parts, etc.

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Pack-hardening compounds for armor plate and deeper cases . . . Liquid carburizers for fast production line hardening.

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Furnishing complete protection against rust . . . the modern Rust Veto line of slushes, oils and greases meeting government and industrial specifications.

HEAT TREATING SALTS

For hardening, reheating, tempering, blackening and treating high speed steel. Pure, stable salts with sharp melting points.

YOUR COMMERCIAL HEAT TREATING

GUIDE

One of these established companies is as conveniently available as your telephone. Let this expert solve those unusual heat treating problems—or call him in to do the complete job, including carburizing, cyanide hardening, nitriding, tool, die, high speed steel and high carbon chrome steel hardening.

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Heat Treating Progress

EDITORIAL

WHY THE COMMERCIAL HEAT TREATER?

BECAUSE:

The heat treatment of metals has become a highly technical and complex subject.

It requires the entire attention of specially trained men—metallurgists for the science, and practiced craftsmen for the art, of modern heat treating.

It is not a job to be handled on the side, nor in anyone's spare time. It is not a thing for amateurs nor dabblers. It requires years of scientific study and years of conscientious, diligent application at the fire. It requires integrity, judgment and skill.

A furnace and a pyrometer will *not* solve your metallurgical problems, any more than a doctor's kit will make you a physician or save you from the pitfalls of "a little knowledge."

The personal factors of training and judgment must be there. There are not nearly enough skilled heat treaters to put one in every manufacturing plant today, to say nothing of trained metallurgists.

The commercial heat treater exists to give you this competent and specialized service. He can often advise you as to economical materials and methods before production starts, and so save you money, time and grief.

His shop must be equipped to handle your every problem in detail or in mass. The work must be done promptly and efficiently, if he is to survive competition.

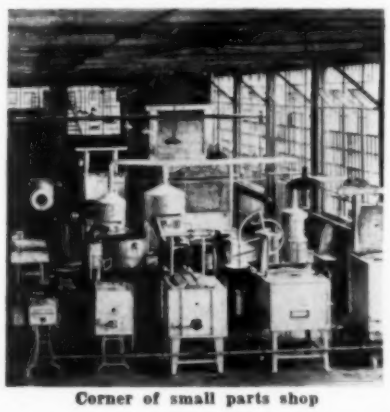
By concentrating men and equipment in a single heat treating plant under expert supervision, the work is expedited, the quality improved, the risk is minimized, and the overall cost is reduced.

It is cheaper, it is safer, and it is wiser to go to the competent commercial heat treater.

HORACE C. KNERR
Consulting Metallurgical Engineer
President, METLAB COMPANY, Phila., Pa.

Truck or RR Delivery

Every kind of heat treating, large or small



Corner of small parts shop

STEPPING UP

METLAB is continually stepping up its equipment and facilities to meet increased demands.

An engineering organization devoted to the commercial heat treatment of metals, in every phase.

Equipped for detail or mass production at minimum cost.

IT PAYS TO ASK

METLAB CO.

NATIONALLY KNOWN

COMMERCIAL HEAT TREATERS

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Consulting Metallurgical Engineer
President and General Manager

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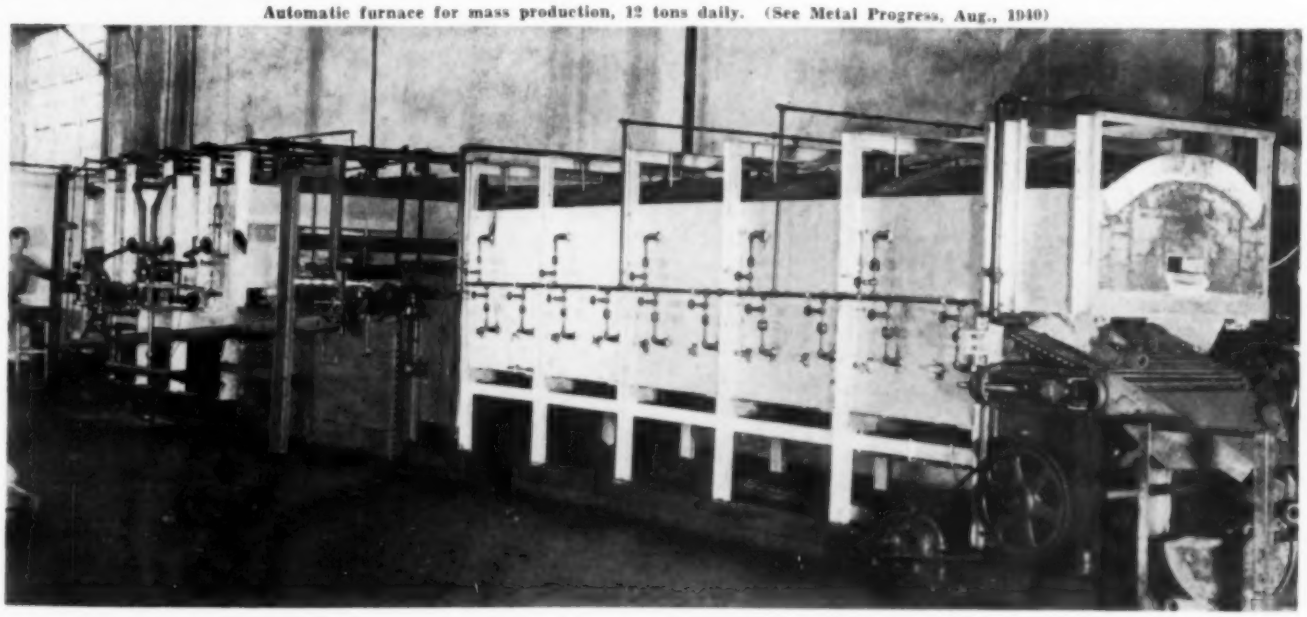
Easy to remember as our address
1000 MERMAID AVE.
Philadelphia, Pa.
Phone: CHEstnut Hill 3500

Automatic furnace for mass production, 12 tons daily. (See Metal Progress, Aug., 1940)



ANOTHER NEW ELECTROPLATING PROCESS

SAVES Time — and that's money saving in any plating plant . . . Better brass plating by methods which are easier and more economical than present practices . . . Heavy or light deposits which are uniform and attractive.

The New High Speed Brass is the modern process for all products which require a smooth lustrous durable brass finish.

It took years of research by du Pont laboratories. It has been tested in the field—by the only practical method—actual installation and operation in commercial plants. The solution is easily made up from a prepared salt of high purity. No unusual plating equipment is required.

Arrange for a demonstration or installation in your own plant. Write or call the Electroplating Division, or the nearest district office.

E. I. DU PONT DE NEMOURS & COMPANY (INC.)

ELECTROPLATING DIVISION

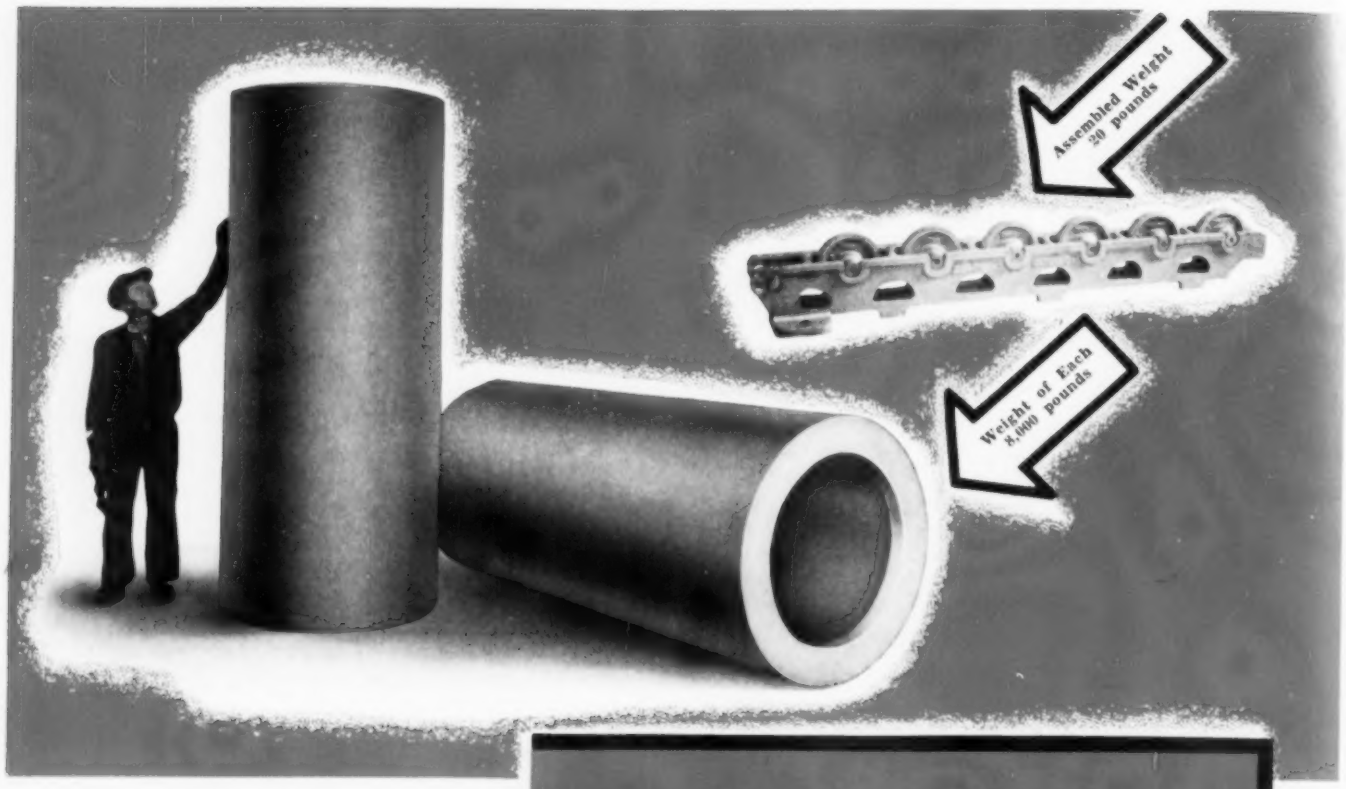
WILMINGTON DELAWARE

Demonstration HIGH SPEED BRASS

At the National Metal Show, you can see an actual demonstration of the new du Pont High Speed Brass plating process. Come any time during the week—bring some of your own work and have it plated right on the spot. See how this advanced process works . . . how you can get heavy or light adherent coatings of bright brass in one-half to one-third the time.

metal progress

heat & corrosion resistant metals



Large or Small...

DURALOY
produces sound chrome-iron and chrome-nickel castings

Soundness in castings is particularly vital in connection with alloys, not only because of the greater investment but because of the special duty to be performed by the castings. They must have quality.

Duraloy, since 1922 specialists in chrome-nickel and chrome-iron, has the experience, equipment and men to turn out sound high alloy castings.

The two photographs above are indicative not only of the range in sizes but of the variety of castings we are producing every day, with rough or machine finish and polished, too, when desired.

We shall be at the National Metal Exposition in Cleveland the latter part of October and will be glad to have you drop in at our booth (G-19) and discuss your casting requirements.

THE DURALOY COMPANY

Office and Plant: Scottdale, Pa.

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Detroit	Scranton, Pa.	St. Louis	Los Angeles
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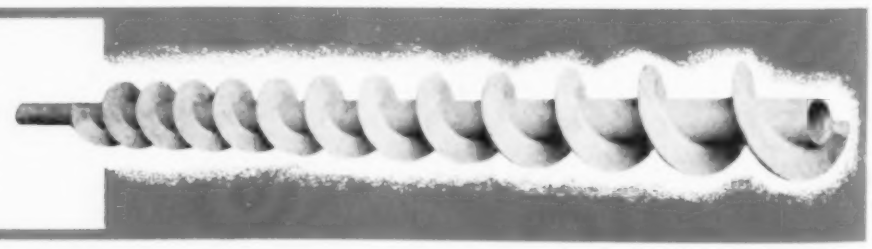
Producing since 1931, we are one of the real pioneers in the centrifugal casting of chrome-iron and chrome-nickel alloys. We offer complete and prompt service on these superior castings, typical of which is the one-piece screw conveyor shown at the right.



Heat and Corrosion Resistant Metals

Supplies of Chromium
(Essential to the Stainless Steels)

By James H. Critchett
Vice-President
Electro Metallurgical Co.

DURING times like the present it is desirable that those concerned with the specification of high grade materials, such as members of the ⚓, be fully informed as to the outlook for the many items involved, especially the items that by reason of importation or small domestic production might become critical. Chromium is one such metal, since its ore is very largely imported and its use has increased steadily in recent years.

Fortunately chromium ores occur in rather widespread areas throughout the world, South Africa, New Caledonia, India, Turkey, and the Philippine Islands being among the leading producers. Smaller quantities of ore have occasionally been obtained from Cuba, Central America, and South America; and the United States, Alaska, and Canada have also produced important quantities in the past under the impulse of increased demand. In fact, during 1918-19 sufficient was mined from domestic sources to supply practically all of this country's needs at that time (and the reserves were in no way depleted) but at a cost, however, considerably above the usual price of imported ore. Today, with the opening of better roads, the increased use of trucks, and the development of tractor types of mining equipment, it would be much easier to produce an even larger quantity of ore from known deposits. Thus domestic ore *in the ground* is an important reserve for the chromium industry of the United States. Also, the fact that ocean shipments would have to be shut off in all directions to keep ore from reaching this country makes the entire stoppage of imports highly improbable.

The manufacturers of ferrochromium, refractories and other chromium products, realizing the possibilities of interruption or delay in shipment of the ores, have always maintained large stocks amounting in cases to several years' requirements under normal conditions and to more than a year's needs under even the most exaggerated demands. This is the situation today; large increase in usage of the metal has reduced the length of time that ore stocks will last but they are still ample and shipments have been coming to the country at an increased rate, so that no emergency is to be anticipated. Should it seem wise, present ore reserves give ample time to start domestic production with which to supplement our resources. The Government's emergency stock pile, which is being accumulated without reduction of commercial stores or receipts, today amounts to an appreciable part of the country's needs and gives added assurance that there will be no shortage of the metal.

Rapid transition from an abnormally low to an equally abnormally high rate of manufacture of any commodity brings strain not only on raw materials, but on manufacturing equipment and personnel. The ferrochromium end of the electro-metallurgical industry has already passed through the transition period, met all current domestic needs, and within a very few weeks will have finished expansion sufficient to meet a still further substantial increase in the rate of use of the alloys.

Modifications of Standard Types

By H. A. Grove
Alloy Steel Division, Republic Steel Corp.

AS ONE LOOKS BACK over the history and growth of stainless steel, he will notice that there has been a recent trend or effort made to simplify and stabilize the basic types. Several of the outgrowths of the basic 18-8 chromium-nickel analysis have been dropped by the American Iron and Steel Institute's list and by the producers in an effort to reduce and simplify the all too numerous grades which were developing. This trend in tube manufacture is discussed on page 384.

It is therefore understandable that there have been very few new varieties of stainless steel developed in recent years. However one new variety which has met with some favor, especially from the aircraft industry, is a modification of A.I.S.I. type 347 (18-8 plus columbium) by adding 2 or 3% silicon. Steel of this analysis combines the good features of both silicon and columbium as addition elements when used in a heat and corrosion resisting capacity, such as for exhaust stacks, collector rings, boilers and heating units.

Also, a joining of existing analyses has brought forth another new type made from the combination of A.I.S.I. types 316 and 347, namely, 18-8 plus molybdenum and columbium. It is hoped in this alloy to combine the stabilizing effect of columbium with corrosion resisting characteristics of molybdenum. How successful it will be is yet to be proven, as the development of any new analysis requires long years of trial, involving both success and failure, until the right applications are reached.

The suggestion that silver be added to 18-8 to minimize its susceptibility to the pitting type of corrosion is also among the new modifications. Its worth is not as yet proven, as in early tests in sea water it failed to show superiority to plain 18-8. It may, however, in later tests find its place in the field of stainless steels.

While these newer varieties of stainless steel are being tried out, one should not forget those basic analyses which are performing so well in industry today. 18-8 with specially balanced chemistry for high tensile work is rapidly being adopted for aircraft structural parts and has proven very useful in high speed streamlined trains.

Type 304 (18-8, low carbon) continues to be used extensively for food and dairy equipment, beer barrels, soft drink drums, and other syrup containers. In the motion picture field, Warner Brothers have adopted this grade, together with type 316 (low carbon 18-8 with molybdenum), for use in their film developing rooms, type 316 being used where acid conditions exist, and type 304 elsewhere.

Type 302 (18-8), which has for a long time been used in the refrigeration industry for evaporator units and assemblies, has recently come into greatly extended application by replacing the tin-dipped shelving formerly used in modern ice boxes and refrigerators. These shelves are made of cold drawn wire formed and welded together to make a grating, the whole then being polished by the newest method of polishing stainless — that is, "bright pickling". This type of shelving is not only pleasing in appearance, but is highly corrosion resistant and sanitary.

Undoubtedly, the chemical industry will put new and more severe demands on the more popular present grades of 304, 316, 317, 321, 347, due to their war contracts and defense requirements. These increasing demands may lead to the development of new grades, as usually happens during periods such as now exist. This will not only be true of stainless steel, but of all steels which must meet the new and ever increasing problems of this age.

Manufacture of Wrought Alloys

By A. L. Feild
Director of Research
Rustless Iron & Steel Corp.

DURING THE PAST YEAR there have been no radical changes or improvements in the fundamental processes of melting and rolling so far as stainless steel is concerned. Nevertheless, the present large production has enabled manufacturers to improve details of technique in the direction of obtaining a higher standard of quality and uniformity, even in the commoner grades. This improvement has been

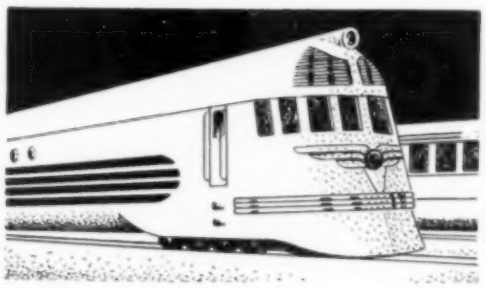
somewhat more noticeable in certain special grades where tonnage has shown a percentage increase greater than the average for the industry — as, for example, in the case of the chromium-nickel grades containing columbium, titanium, and molybdenum as well as in certain free-machining grades. There has also been a definite trend toward a higher yield from ingot to finished product in these special grades, principally by virtue of improved hot working properties and closer control of hot rolling temperatures. Improvement in hot working properties may be attributed not only to greater care and skill in furnace technique and pouring practice, but also to certain modifications in chemical analysis.

Increasing attention is being paid to perfection of surface in rolled and drawn products, both before and after special surface treatment, and to the presence of defects such as hair-line cracks especially in the hardenable, straight chromium grades. A definite improvement in the surface obtainable on polished articles of the cutlery type has been achieved.

The rapid development of anodic electrolytic treatment as a polishing means for fabricated articles has had, as a collateral development, the use of this new process of "electrolytic polishing" as a routine inspection tool for certain finished products such as cold drawn stainless steel wire.

Bright annealing in an atmosphere of cracked ammonia (free from water vapor) has been successfully used in large tonnage applications — especially for wire, where its use presents fewest difficulties from the engineering standpoint.

There has been a considerable increase in the production of stainless steel wire, and more rapid drawing speeds have materially speeded up output. Chromium-nickel wire for cold upsetting operations is finding increased applicability where the rate of hardening by cold work is carefully controlled by selecting the correct chemical composition.



Expanding Markets for Stainless

By Paul F. Voigt, Jr.
Manager, Stainless Steel Division
Carnegie-Illinois Steel Corp.

INDUSTRY as a whole has come to a definite realization of the importance of the stainless alloys. Producers of the steels have increased their capacities and improved their facilities to supply the constantly increasing and ever widening demand for materials to withstand corrosion, to reduce weight and to resist heat. Users and prospective users are vitally interested in new developments and new applications and, consequently, are very receptive to sales solicitation. Added to normal domestic needs, the demands brought about by the international emergency have increased stainless tonnage to a figure far in excess of that produced in any previous period.

While the use of stainless steels extends into every kind of industry, and in ways too numerous to cover individually, the following notes regarding specific fields of application are of interest:

Chemical and Powder Plants — Completely immune to the effect of many strong acids, stainless has been widely used for tanks, digesters and other miscellaneous equipment used in the chemical and explosive industries — which are of the most importance under present day conditions.

Aircraft — Stainless manifolds have successfully passed the most rigorous tests of all — actual service tests of 5000 to 7000 hr. of flying time. Highly satisfactory results have been secured on firewall installations, on bomb chutes, tail surfaces and other parts requiring high tensile stainless for strength and weight reduction.

Oil Industry — Today finds prominent refiners in all parts of the country installing all-stainless bubble towers, trays, caps and liners in their present towers and specifying them in new equipment, because all installations to date indicate that the stainless tray is a most effective means of reducing operating expense. Liners of stainless steel in other refinery vessels and heat resistant alloy tubes are important factors in this field.

Transportation — In addition to the more widespread use of stainless steel in rail car construction, the application has been broadened to include busses and trailers. This fol-

The A-B-C of Corrosion and Heat Resisting Steels

Arrangement due to F. R. Palmer. Adapted from The Book of Stainless Steels," Second Edition

	Group A (Martensitic)	Group B (Ferritic)	Group C (Austenitic)
Chemical Analysis	Chromium less than about 16%; carbon less than about 0.40%. May contain small percentages of tungsten, copper, nickel, silicon, columbium, aluminum, and more frequently molybdenum. Group is magnetic.	Chromium more than about 16%; carbon quite low, but can increase as chromium goes up. May contain small percentages of copper, nickel, silicon, molybdenum, tungsten, nitrogen. This group is magnetic.	Contains enough nickel to make steel austenitic and non-magnetic. They usually contain twice as much chromium as nickel or vice versa; total alloy content at least 26%. Carbon quite low. (Manganese sometimes substituted for nickel, in part.)
Heat Treatment	Respond to hardening and tempering. Resulting physical properties depend on chemical analysis (principally carbon content).	Do not respond. 18% chromium toughened by long anneal at more than 1400° F., and air cooling. Avoid decarburizing the skin. 25% chromium gets best strength and toughness by rapid cooling from 1650°.	Do not respond to hardening by heat treatment. Must be rapidly cooled from soaking heat at 1900 to 2150° F. to retain austenitic structure free of carbides. (Brinell 140 to 170).
Toughness	Are structurally dependable. After tempering are not brittle in notched sections or under impact.	Laminated structure, from coarse ferrite in ingot, causes low impact values, but proper rolling and heating gives adequate toughness in rods, bars, and sheets. Structure is refined by alloying with nitrogen.	Extremely tough at all temperatures down to liquid air. Dependable against shock except when corroded at grain boundaries (a preventable condition).
Grain Growth and Structural Changes at High Temperatures	Not subject to excessive grain growth. Thoroughly dependable for supporting any load or shock within their carrying capacity up to 1400° F. Brittleness in plain chromium steels when cooled after long heating is avoided by addition of molybdenum.	The chromium-irons low in carbon and those high in silicon or aluminum (when cold worked) are subject to excessive grain growth, especially above 1900° F. Grain growth reduced by nitrogen. Long service at 800 to 950° F. makes them brittle when cold, although they are not brittle at working temperatures.	Alloys near the austenite-martensite border line tend to precipitate carbides at grain boundaries during service at 800 to 1600° F., losing some toughness and becoming susceptible to intergranular attack. This is controlled by very low carbon, by titanium or columbium, by increasing the chromium and nickel, or by prior "stabilization."
Strength at Elevated Temperatures	Much better than straight carbon steel for temperatures up to 1000 or 1200° F. Retain tensile properties up to 750° F.	Heat resisting varieties quite tough at temperatures up to 1600° F. Superior in ductility to Group C but not in creep resistance.	Have high creep strength up to 1200 F. which is enhanced by tungsten or molybdenum. Toughness impaired in non-stabilized alloys by service at 800 to 1600° F.
Hot Working Qualities	Readily forged, pierced, or rolled at 2000 to 1700° F. Preheat and soak stock at 1600° F. Plain chromium alloys air harden on cooling.	May be forged, rolled, or pierced. Should be heated quickly. Forge from 2200° F. down to 1750° F. On last heat continue cold working to 1400° F. to refine grain. Alloys do not air harden.	May be forged, rolled, or pierced. Preheat and soak at 1600° F., heat quickly to 2200° F., forge down to 1850° F. Hot short range: 1800 to 1300° F. Alloys do not air harden.
Cold Working Qualities	Low carbon varieties can be easily cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn.	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn, especially when warm (300 to 500° F.).	Can be cold drawn into wire, cold rolled, bent, formed, upset, coined, and deep drawn. Work-harden twice as rapidly as Groups A and B.
Machinability	Machine satisfactorily with properly designed tools when heat treated to 200 to 250 Brinell. Free-cutting grade contains complex sulphides or selenium.	Machine satisfactorily with properly designed tools. Cold working and high sulphur or selenium improve machinability.	Most difficult of all even with super high speed and carbon tools. Use sharp tools having greater top rake than usual, and cut continually. Free-cutting grade contains selenium and phosphorus.
Riveting	Make excellent cold rivets. Air hardening, high chromium steels not recommended for hot rivets driven above 1500° F.	Extra precautions required to avoid brittle rivets. Conical heads should be cold upset on ground bars; rivets driven at 1425° F. into chamfered holes.	Excellent for either hot or cold rivets. Hot rivets may be driven at a high temperature (1900° F.).
Welding Properties	Preheated parts can be welded with gas, electric arc, or resistance. Anneal immediately before weld air hardens. Little grain growth. Columbium or aluminum increases ductility of welds.	Can be welded. Anneal at 1450° F. to reduce embrittlement alongside weld. Those metals subject to grain growth are brittle adjacent to the weld. Those metals not subject to grain growth yield satisfactory welds.	Can be welded with gas, electric arc, or resistance, if carburization is avoided. Weld does not air harden and is very tough. Only the very low carbon or the "stabilized" metal should be welded if article must resist corroding media.
Corrosion Resistance	Increases with chromium content; inferior to Groups B and C. Resists weather, water, steam, and mild corrodents when chromium is 11.5% or more. If carbon is relatively high, metal must be hardened and tempered (below 1000° F.).	Possess corrosion resisting properties superior to Group A; increases with chromium content. Especially good for nitric and other oxidizing acids.	Corrosion resistance depends largely upon total alloy content. Resists nearly all corrodents measurably better than Groups A and B; especially good for organic acids. Severe pitting may occur in stagnant chloride solutions under particles of foreign matter and along faying surfaces.
Scale Resistance	Increases with chromium content. Generally useful for continuous temperatures up to 1200° F., and in some services up to 1500° F.	Superior to Group A, especially when chromium is above 25%; then resist reducing atmospheres up to 2100° F., resist oxidizing gases up to melting points, and sulphur gases up to 1800° F.	Excellent where combination of high temperature and corrosion is to be met. High chromium, low nickel alloys required to resist sulphurous gases. Addition of 2 to 3% silicon markedly improves scale resistance.

lows the development which has taken place over a period of years. Stainless is widely used in truck tanks for the transportation of milk and recently for various soft drinks.

Automotive — Stainless steel automobile trim continues to expand in tonnage and represents the largest single outlet for this material.

Refrigeration — In addition to the large amount of tarnish-free metal now being used for evaporators and trim, the use of stainless steel wire is growing for shelving. The trend is definitely toward increased tonnage in this field.

Dairy Industry — Stainless steel is the ideal material for the treatment and handling of milk. The dairy industry is outstanding in its widespread use for pasteurizers, holding tanks, truck tanks, coolers and miscellaneous equipment.

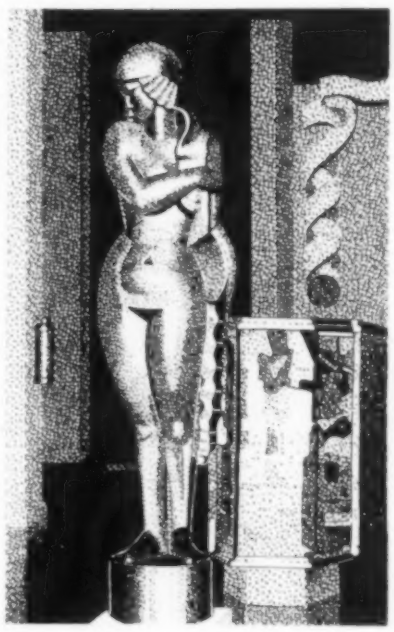
Stainless Steel for Decorative Effect

By C. B. Templeton
Assistant to President
Allegheny Ludlum Steel Corp.

THE TITLE must not be taken too literally. It is questionable whether anyone uses stainless steel *purely* for decorative effect. True, it all started that way when, in the 1920's, bright metal appointments became the modern style note in interior and exterior decoration. At first, the field was largely restricted to plated metals; since stainless and other solid, corrosion resistant materials like aluminum and monel were just becoming available in the forms needed. But, once arrived, it was the *additional* attributes of stainless and these other solid metals which quickly gained and held supremacy in the decorative field.

Let us say, then, that those who use stainless steel for decorative purposes do so primarily because they also acquire thereby a high degree of utility; and that those who employ it for utility's sake gain immense added value from its everlasting beauty.

(Continued on page 476)



Stainless Steel the Next Step for Aircraft

William B. Stout
President, Stout Skycraft Corp.

WITH the very sudden increase in interest in aviation and the great activity in the attempts to bring out planes in quantities, the most obvious detriment to production is — rivets. The common air transport contains from 250,000 to 350,000 of these pesky little things, all put in by hand. The strato liner has something like 700,000 at a cost of something like 5¢ each, to say nothing of the cost of the time in building. For this reason, we must come to a new method of production which will allow welding.

Developments in welding in the last six months have been so startling as to open up entirely new fields of structural activity. On top of that, stainless steel has appeared for the first time in thin gages and fairly wide sheets, applicable to aircraft use. To my notion, therefore, wide utilization of stainless steel represents the next step in aircraft development and a necessary step before real production can be had in airplanes.

Strong, heat treated aluminum alloys, which have already been used so widely, can be welded — but on account of the heat of the weld, the metal at the weld itself turns back to nothing but the cast aluminum alloy, with comparatively little strength. It is, therefore, open to doubt whether duralumin can be successfully welded for important structural parts.

Stainless steel, however, is one of the best materials for welding and falls naturally into a class of production separate from any other material.

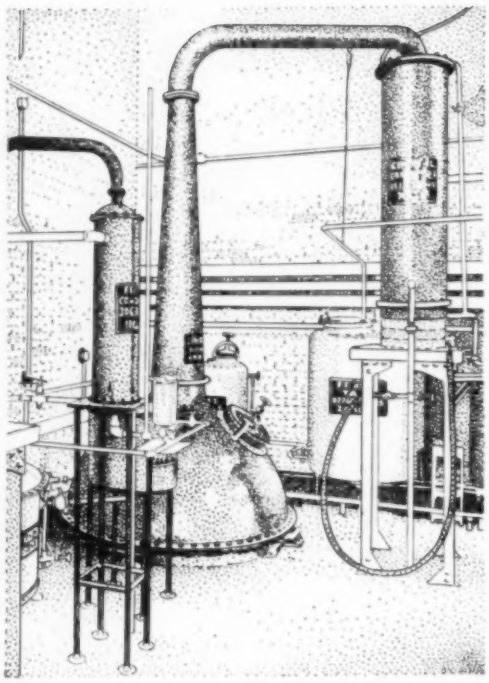
Designing aircraft structures primarily for stainless steel, rather than copying old-type structures and building them of stainless steel, will allow us very shortly to better any previous airplane weights, but with greater strength and rigidity and at a fraction of the structure cost of old-type planes.

The problems are many — purely from the standpoint of the airplane man — but the rewards will be great, while

the volume of steel used in the industry will in the end be a surprise to those who have been thinking of aviation in terms of our present planes and present production.

Stainless steel is the next step for aircraft.

While it is the general opinion that military aircraft, particularly in this present emergency, offers a great opportunity, yet many more planes are being built for private owners and commercial transport than are being built for all military services, and with a larger margin of profit, and a greater value per purchasing dollar.



Since these planes are not built with the design restrictions required in military planes for bomb racks, machine guns, cannon, and armor, development of small planes and their sale in large quantities can be the real backbone of national defense for the training of thousands of pilots, and also the foundation for entirely new developments in bigger, lighter and stronger transport planes for passengers, freight, Army or Navy. All these aircraft can undoubtedly be built easily and rapidly — once this technique of stainless steel design in minimum weight has been solved.

Our firm built the first all-metal airplane in the United States. It was made of duralumin. We now hope to be the first to develop, in practical mass production, stainless steel constructions which can lead the American aircraft industry to new heights.

Stainless Steels in the Defense Program

By Philip L. Coddington

IN World War I, stainless steels were little known and had not reached a point of development which would make them available for use in chemical and process equipment. Explosives at that time were produced in vessels which have long since succumbed to the ravages of corrosion, if they have not sooner been retired on account of obsolescence.

Today raw materials as well as the finished explosives therefrom are processed almost without exception in stainless steel. In the present preparedness drive many millions are being spent for equipment of this sort. It should be a source of satisfaction that, barring accidents, this stainless steel equipment will be entirely serviceable 25 years hence.

It is fortunate that peacetime developments have brought the manufacture of numerous stainless steels and the production of equipment from them to such a high degree of efficiency, for emergency requirements are being quietly and promptly met.

For defense purposes high grade motor fuels are just as essential as explosives. No country in the world compares with the United States in quality and productivity in this field. Stainless equipment has played an important role in the many important developments since 1915 which have maintained the petroleum industry in this country in a position of world leadership. It is playing an increasingly important role in the latest polymerization and catalytic processes.

The chemical and process industries have also been confronted with many urgent problems brought about by the defense program. The prospect of being cut off from supplies of various raw materials has speeded development of numerous processes. In certain of these rather closely guarded processes the chromium-nickel stainless types have been found most useful because of their high strength and impact values at subzero temperatures — entirely aside from their corrosion resistance.

Finally, in a world which is so busily planning mass destruction of human life, it is interesting to note that important developments are taking place in the bio-chemical and pharmaceutical field. Here stainless has recently been playing a most important part. Through its use as equipment for the perfection of new remedies and antiseptics, stainless steel is doing its bit toward healing the world's wounds and curing some of its ills.

Metals for High Temperature Service

By J. J. Kanter
Research Metallurgist, Crane Co.

CONSTRUCTION of many new plants in the oil refining and power industries for operation at extremely high temperatures has introduced a number of metallurgical problems. Catalytic and alkylation processes are particularly exacting in their service requirements. Here the materials must not only have qualities making for high temperature strength, but must also have a high order of chemical resistance and stability. In such work, pressure piping and its accessory equipment is trending decidedly toward the more highly alloyed steels, both ferritic and austenitic. More emphasis than ever is being placed upon the use of stable compositions of high alloy steel, and recent metallurgical investigations, both domestic and abroad, have thrown considerable light upon the iron-nickel-chromium steels and the various factors in their composition and treatment affecting their stability and chemical resistance. These investigations are proving an invaluable guide to the engineers responsible for the design and construction of the new power plants and refineries.

Under the impetus of high temperature plant design, the Boiler Code Committee of the American Society of Mechanical Engineers has recently proposed a comprehensive table of working stresses for steels usable at temperatures up to as high as 1200° F. These proposed stresses represent a digest of much research and testing of steels at high temperatures as well as operating experience.

The use of non-ferrous metals at high temperatures has so far been rather limited, and it has been suggested that certain of the new service problems encountered might be met through their use. Although copper-base alloys generally have definite limitations in their high temperature strength as compared to steels, their chemical properties do, in some instances, afford merits. More study is needed upon their high temperature properties so that the code committees might set comprehensive working stress tables for non-ferrous metals, as has been done for the steels. In the A.S.T.M.-A.S.M.E. Joint Committee for Research on the Effect of Temperature on Metals, such a research project has been organized.

There can be little question that today's knowledge of the engineering properties of metals and alloys is definitely more mature than a decade ago. Although startling new discoveries in the way of hitherto unknown combinations of elements and properties may not be apparent, we do have a better understanding of the practical worth of economical materials of construction, and we have progressed in the ability to evaluate their engineering usefulness. It would seem that metallurgists and engineers are becoming more sophisticated in their dealings with materials, and rather than multiplying their efforts to produce ever new and radically different substances, are devoting an ever increasing effort to the rational treatment and application of those already known.

Stainless Clad

By T. S. Fitch
Manager, Composite Steel Division
Jessop Steel Co.

FOR ANY APPLICATION in which corrosion resistance of one surface only is necessary, clad steels present a definite economy. Such metals as stainless iron, stainless steel, nickel and copper are all relatively expensive and thus, in homogeneous form, material costs are high. By using relatively inexpensive mild steel for the major portion of the plate or sheet, the net value of the clad article may be substantially reduced — savings of as much as 45% are often possible.

The introduction of clad metals for equipment and structures on a commercial basis dates back about ten years. In these early days of the clad steels there was very considerable difficulty with the "bonding" — that is, effecting a strong union between the components. In fact, the difficulties were sufficient to raise serious question in the minds of many fabricators and users regarding clad steels in general. Within the last five years methods have either been developed or perfected which result in entirely satisfactory "bonds", and it is now relatively rare to encounter difficulty in this respect with the commercial products.

As is indicated in the outline on page 383, several successful methods are used in the production of clad steels — casting, hot rolling, electrodeposition of iron and hot rolling, spot welding, continuous welding and intermelting are all being successfully used. In some cases one method is more economical than another; thus, consideration should *(Turn to page 466)*

Properties of the Principal Cr-Fe Alloys

	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
Chemical composition							
Chromium	1.75 to 2.25	4 to 6	8 to 10	12 to 14	13 to 14	16 to 18	25 to 30
Nickel	(0.5 Mo)	—	(1.5 Mo)	—	—	—	—
Si and Mn (max.)	0.50	0.50	0.50	0.50	0.55	0.50	0.50
Carbon	0.15 max.	0.10 to 0.20	0.15 max.	0.10 max.	0.30 to 0.40	0.10±	0.10±
Specific gravity							
Lb. per cu. in.	—	0.280	0.282	0.276	0.278	0.273	0.270
(Mild steel = 1.00)	—	0.99	1.00	0.97	0.98	0.96	0.95
Electrical resistance at 70°F							
Microhms per cm^3	—	—	—	57	60	59	67
(Mild steel = 1.00)	—	—	—	5.2	5.5	5.4	6.1
Melting range, °F.							
Top	—	2800	—	2790	2750	2750	2750
Bottom	—	2760	—	2750	2580	2710	2710
Structure (normal)	Pearlitic	Pearlitic	Martensitic	Martensitic or Ferritic	Martensitic	Ferritic	Ferritic
Magnetism							
Ferromagnetic	Yes	Yes	—	Yes	Yes	Yes	Yes
Permeability: As annealed	—	—	—	—	—	—	—
Permeability: Cold worked 10%	—	—	—	—	—	—	—
Specific heat							
C.g.s. units, 0 to 100°C.	—	0.11	—	0.11	0.117	0.11	0.11
(Mild steel = 1.00)	—	1.0	—	1.0	1.1	1.0	1.0
Thermal conductivity							
*C.g.s. units at 100°C.	—	0.0874	—	0.0595	0.05	0.0583	0.0500
(Mild steel = 1.00)	—	0.73	—	0.50	0.42	0.49	0.42
C.g.s. units at 500°C.	—	0.0803	—	0.0686	—	0.0624	0.0583
Thermal expansion per °F. x 1,000,000							
From 32 to 212°F.	—	6.1	6.29	6.1	5.7	6.0	5.9
(Mild steel = 1.00)	—	0.93	0.95	0.93	0.87	0.91	0.90
From 32 to 932°F.	—	7.2	7.00	6.7	6.6	6.7	6.3

Mechanical Properties at Room Temperature	2% Cr: Annealed	5% Cr: Annealed	5% Cr: †Heat Treated	9% Cr: Annealed	12% Cr: Annealed	12% Cr: †Heat Treated	Cutlery: Annealed	Cutlery: ††Heat Treated	17% Cr: Annealed	17% Cr: Cold Worked (Wire)	27% Cr: Annealed	27% Cr: Cold Worked (Wire)
Ultimate strength, 1000 psi.	60 to 70	66	115	75 to 87	65	125	100	230 to 260	75	100 to 190	75 to 95	85 to 175
Yield point, 1000 psi.	30 to 45	27	103	35 to 45	35	100	65	200 to 220	40	—	50 to 60	55 to 155
Elastic modulus, 10^6 psi.	—	—	—	—	28	—	—	—	29	—	—	—
Elongation, % in 2 in.	40 to 30	38	20	40 to 30	35	20	27	8 to 2	27	—	30 to 20	—
in 10 in.	—	—	—	—	—	—	—	—	—	25 to 2	—	25 to 2
Reduction of area, %	—	76	66	—	65	60	59	20 to 2	55	40 to 20	60 to 50	55 to 25
Impact, ft-lb., Charpy	35 to 65	—	—	35 to 60	—	75	—	—	—	—	—	—
Izod	—	80	75	—	80	—	—	—	8 to 25	—	—	—
Fatigue endurance limit, 1000 psi.	—	—	—	—	—	—	—	—	48	—	50	—
Corresponding ultimate strength									76		78	
Hardness, Brinell	130 to 160	136	250	145 to 180	140	230	170	480	175	185 to 270	160 to 190	150 to 250
Rockwell	—	B-75	C-24	—	B-76	C-22	—	C-56	B-85	B-90 to 105	B-80 to 90	C-0 to 25
Erichsen value, mm.	—	—	—	—	—	—	—	—	7 to 9	—	—	—

Stress in psi. causing 1% "creep" in 10,000 hr. at	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
1000°F.	11,400	7,000	11,600	13,000		8,500	—
1100	5,650	—	6,950	5,200		5,200	—
1200	3,150	—	2,300	2,100		2,100	1,600
1350	—	—	—	1,400		1,200	400

	2% Cr	5% Cr	9% Cr	12% Cr	Cutlery	17% Cr	27% Cr
Scaling temp., °F.		1200	1200	1300	1750	1550	2100
Initial forging temp., °F.		2100	—	2100	2000	2000	2200
Finishing temp., °F.		About 1400	—	max. 1450	1700	max. 1400	max. 1400 to 1450
Annealing treatment		Furnace cool from 1580°F.	—	Prolonged heating at 1250 to 1350°F.	1575 to 1625°F.	**	1 hr. or more at 1450°F. and quench

* Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.
† Quenched and drawn at 1100°F. †† Oil Quenched from 1850°F. and drawn.
** Small cold reduction, followed by anneal at 1400°F. and quench

Properties of the Principal Cr-Ni-Fe Alloys

	18-8		18-12	25-12	25-20	18-26
Chemical composition						
Chromium	17 to 19	Modifi-	17 to 19	22 to 28	24 to 26	17.5 to 19.5
Nickel	8 to 10	cation	11 to 12.5	12 to 16	19 to 21	25 to 26
Si and Mn (max.)	0.50	with	0.50	—	1.0 & 0.75	3.0 Si max.
Carbon	0.10	titanium	0.10	0.15±	0.15 max.	0.20 max.
Specific gravity						
Lb. per cu. in.	0.286	0.285	0.287	0.283	0.285	0.280
(Mild steel = 1.00)	1.01	1.01	1.02	1.0	1.01	0.99
Electrical resistance at 70°F.						
Microhms per cm³	70*	71	73	78	90±	102
(Mild steel = 1.00)	6.4	6.5	6.7	7.1	—	9.3
Melting range, °F.						
Top	2590	2590	—	2570	2600	—
Bottom	2550	2550	—	2530	2550	—
Structure	Austenitic	Austenitic	Austenitic	Austenitic	Austenitic	
Magnetism						
Ferromagnetic	—	—	—	—	Trace	—
Permeability — As annealed	1.003	1.003	1.003	1.003	1.003	—
Permeability — Cold worked 10%	1.10	—	1.006	1.003	—	—
Specific heat						
C.g.s. units, 0 to 100°C.	0.12	0.12	0.12	0.12	—	—
(Mild steel = 1.00)	1.1	1.1	1.1	1.1	—	—
Thermal conductivity						
**C.g.s. units at 100°C.	0.0390	0.0385	0.0380	0.03 to 0.04	0.03 to 0.04	—
(Mild steel = 1.00)	0.33	0.32	0.32	0.25 to 0.35	0.25 to 0.35	—
C.g.s. units at 500°C.	0.0515	0.0528	0.0520	—	—	—
Thermal expansion per °F. x 1,000,000						
From 32 to 212°F.	9.6	9.3	9.9	8.3	8.8	8.8
(Mild steel = 1.00)	1.45	1.40	1.50	1.26	1.33	1.33
From 32 to 932°F.	10.2	10.3	10.8	9.6	9.4	9.3

Mechanical Properties at Room Temperature	18-8 Annealed	18-8 Cold Worked (Wire)	18-8 †Stabilized	18-12 Annealed	18-12 Cold Worked (Wire)	25-12 Annealed	25-12 Cold Worked (Wire)	25-20 Annealed	18-26 Annealed
Ultimate strength, 1000 psi.	80 to 95	105 to 300	80 to 95	80 to 90	105 to 275	90 to 110	110 to 270	80 to 110	90 to 110
Yield point, 1000 psi.	35 to 45	60 to 250	40 to 45	40	—	40 to 60	65 to 230	35 to 65	45 to 50
Elastic modulus, 10^6 psi.	29	—	—	—	—	—	—	—	30±
Elongation, % in 2 in.	65 to 55	—	60 to 50	60	—	50 to 35	—	60 to 45	35 to 30
in 10 in.	—	50 to 2	—	—	50 to 2	—	35 to 2	—	—
Reduction of area, %	65 to 55	65 to 30	65 to 55	65	65 to 30	60 to 45	55 to 20	—	45 to 35
Impact, ft-lb.; Charpy	80	—	77	—	—	—	—	40 to 80	—
Izod	75 to 110	—	—	—	—	—	—	—	50 to 90
Fatigue endurance limit, 1000 psi.	35	94	48	—	—	52	—	—	—
Corresponding ultimate strength	90	150	90	—	—	110	—	—	—
Hardness, Brinell	135 to 185	170 to 460	135 to 185	135 to 165	170 to 380	150 to 185	170 to 375	130 to 190	160 to 185
Rockwell	B-75 to 90	C-5 to 47	B-75 to 90	B-75 to 85	C-5 to 40	B-80 to 90	C-5 to 40	—	—
Erichsen value, mm.	11 to 14	—	—	—	—	—	—	—	—
Stress in psi. causing 1% "creep" in 10,000 hr. at 1000°F.	17,000							—	7,000
at 1200	7,000							7,400	—
at 1350	3,000							3,300	—
at 1500	850							1,100	—
at 1600	—							—	1,900
Scaling temp., °F.	1650		1650	1650		2100		2000	1650
Initial forging temp., °F.	2200		—	As for 18-8		2200 to 2300		—	1950
Finishing temp., °F.	Not under 1600 to 1700		—	As for 18-8		Not under 1600 to 1700		—	—
Annealing treatment	Heat at 1900 to 2000°F. and quench		††	As for 18-8		Heat at 2000 to 2150°F. and quench		—	As for 18-8

* Electrical resistance of cold worked 18-8 ranges from 70 to 82 microhms per cm. cube

** Thermal conductivity is measured as calories per sq. cm. per sec. per °C. per cm.

† Small cold reduction, followed by anneal at 1400°F. and quench

†† Final heat treatment must consist of 2 to 4 hr. soak at 1550°F.

be given to the application. For example, a ⅛-in. thick stainless sheet may be bonded to a 2-in. thick mild steel plate most economically by spot or seam welding. On the other hand spot welding is not the best procedure for plates in the neighborhood of ¾ in. thick. There are advantages claimed for one method over another but the significant fact is that each product has been and is being used in service with satisfaction.

There has been in the minds of many potential users a considerable question as to the usefulness of clad metals in view of the presence of dissimilar metals. In actual practice it has been found that the theoretical difficulties (such as different coefficients of expansion) have not caused any real trouble. For instance, tests have been made on clad material as high as 1700° F. with no separation of the components.

Until lately there was a scarcity of technical information on the subject of clad metals but the literature is rapidly expanding. Special forms of tests and special types of heat treatment have been developed and specific properties have been determined by the producers. In short, clad metals are growing to maturity.

At the present writing the clad metals are being used primarily in the chemical, petroleum, food, textile and paper and pulp industries. Some use is being made in the decorative fields but so far a comparatively small quantity has been utilized in light gage work, such as automobile trim. Since the major saving is possible on plates and on relatively heavy sheets, these were first developed. It is not impossible that the lighter gage clad steels may also be made commercially significant, through some collateral advantage (such as workability) that will be strongly reflected in the overall cost.

So far as the future is concerned, this should be a rapidly growing field and should eventually assume very substantial proportions. The material has a natural economic importance because it enables a reduction in cost with equivalent service life. Should the United States become involved in a war, the clad steels should assume further importance because they enable conservation of various alloys which are not easily obtained in this country.

Nickel, Inconel, Monel

By H. E. Searle
Manager of Engineering Sales
Monel and Rolled Nickel Dept.
International Nickel Co.

OF OUTSTANDING importance in the family of nickel alloys is the group usually associated with rolled nickel. These include among others Monel, Inconel, "K" Monel, and "Z" Nickel. Primarily used to defeat corrosion and to preserve product purity in many industries, rolled nickel and Monel have served a wide range of requirements for over 30 years.

Further specialization came almost 10 years ago with the introduction of Inconel — containing approximately 80% nickel, 14% chromium, and 6% iron. Combining most of the characteristics of nickel and Monel, it added an even higher degree of resistance to elevated temperatures, a slightly different range of corrosion resistant properties and unique spring qualities.

Since the introduction of Inconel, additional specialized alloys have come with "K" Monel and "Z" Nickel. Both are heat treatable to provide strength and hardness usually associated only with the alloy steels. During the past year there has been a notable increase in their use.

Applications of "K" Monel for heavy duty pump shafts and other items of equipment where high resistance to corrosion must be combined with strength and exceptional wear resistance, are mounting significantly. "Z" Nickel (98% Ni), whose mechanical properties run even higher, is expanding in use for electrical applications and for spring purposes, where its unusual fatigue resistance is a big factor.

Still another trend is the use of Inconel sheet for the construction of carburizing boxes, nitriding furnace linings, carburizing trays, airplane exhaust manifolds, and other equipment exposed to high temperature, where the alloy is replacing much heavier castings.

As the demand for special duty materials grows more urgent, some of the casting alloys are coming more and more to the fore — led by "S" Monel. Non-galling and highly resistant to wear, it is an important material for valves,

valve trim, liners, and for similar purposes.

In wider markets, both rolled nickel and Monel are keeping proportionate place with the newer members of the group. Increase in general industrial activity naturally calls on a widening scale for corrosion resistant materials, especially since the requirements everywhere are for equipment offering long life, better performance, and improved products.

Heating Element Materials

By Erich Fetz
Research Metallurgist, Wilbur B. Driver Co.

IMPROVEMENT of the 80-20 nickel-chromium alloy — marketed as "Tophet", "Nichrome", or "Chromel" — has been quite remarkable during recent years. METAL PROGRESS has repeatedly called attention to this metallurgical progress, as well as to the A.S.T.M. accelerated life testing method which is intimately connected with the development. As the "life" at elevated temperatures has been increased over 20 times since 1935, the question arises as to the limit of further improvements. One ultimately limiting factor must now be faced squarely, namely the comparatively low melting point (about 2550° F.) of the 80-20 alloy.

Very little information has been published on the relatively new heating element materials based on iron-chromium-aluminum alloys and marketed as "Alchrome", "Kanthal", "A. O. Smith No. 10". Their aluminum content ranges from 3 to 6%, depending on the manufacturer. Metallurgical and commercial interest is naturally attracted by their impressively high melting point, which is about 200° higher than that of 80-20. Furnaces are reported to have run thousands of hours at 2400° F. while the maximum service temperature of 80-20 is about 2100° F.

Although the use of Fe-Cr-Al alloys for heater purposes was proposed in this country as early as 1912 (U. S. patent No. 1,057,754) the commercial development and application has been largely in Europe. The endeavor to become independent of the "strategic" nickel by using an iron-base alloy probably constitutes a very important reason why nickel-chromium alloys have been partially replaced over there. The lower costs of the raw materials — ferrochromium, aluminum and iron at one hand and pure chromium metal and nickel at the other — may have also attracted European metallurgists in their all-embracing search for cheaper and cheaper *ersatz* alloys. However, the raw material costs are multiplied by the enormous difficulties involved in the manufacture of the iron-chromium-aluminum alloys. As a matter of fact, a period of several years of intensive research work was required before these tremendous difficulties were gradually overcome. Special melting and hot and cold working processes had to be developed to convert them from the hard, brittle, coarse-grained, as-cast state into ductile wire and ribbon.

Their introduction as heater alloys has been and is still being retarded in America by lack of information on the proper methods of testing and inadequate furnace design. The A.S.T.M. accelerated life testing method, especially designed for the nickel-chromium resistors, is misleading as to the true value of more refractory alloys. Due to their low strength at elevated temperatures, this test indicates a "useful" life (to 10% increase in resistance) of only a couple of hours at say 2150° F., while industrial furnaces have been operated for thousands of hours at considerably higher temperatures.

Likewise the old principles of furnace design had to be radically revised. In contradistinction to nickel-chromium, iron-chromium-aluminum heating elements must be extensively supported and be protected against mechanical injury. With these precautions in mind, good service may generally be expected from them at extreme temperatures, especially where 80-20 fails to operate. In sulphur bearing atmospheres or in contact with media containing sulphur, as for instance kieselguhr and some grades of asbestos, nickel-chromium alloys are destroyed rapidly. Here, a field is wide open for the iron-chromium-aluminum resistors, which, at the other hand, cannot be recommended in dissociated ammonia, for instance, as both chromium and aluminum eagerly react with nitrogen.

Each class of resistor material has evidently its distinct advantages and shortcomings and some characteristic features make each alloy non-competitive in certain fields of application. We are bound to hear more about the iron-chromium-aluminum alloys in this country from our own manufacturers. Formerly much of it was imported, but we have been cut off from former European supplies. Americans have lately succeeded in overcoming most of the production difficulties and the result is lower manufacturing costs.

Engineering Properties of Monel Metal

Data from
International Nickel Co., Inc.

MONEL METAL is a solid solution of nickel and copper approximately 67:30, with added elements to control certain properties. Typical compositions are as shown at right:

PRODUCT	NI	CU	FE	MN	SI	C	AL	S
Wrought; Regular	67	30	1.4	1.0	0.1	0.15	...	(Note)
"K" (heat treatable)	66	29	0.9	0.4	0.25	0.15	3.3	0.005
Cast; Regular	67	29	1.5	0.9	1.25	0.3	...	.....
"H" (high strength)	65	29.5	1.5	0.9	3.0	0.1	...	... .
"S" (non-galling)	63	30	2.0	0.9	4.0	0.1	...	.....

(Note) A high sulphur variety called "R" Monel is free machining.

Properties of Monel Metal Castings

PROPERTY	REGULAR	H MONEL	S MONEL
Tensile strength (1000 psi.)	65 to 80	70 to 90	90 to 115
Yield (1000 psi. for 0.5% extension)	32 to 40	45 to 65	70 to 90
Elongation (% in 2 in.)	45 to 25	20 to 10	3 to 1
Izod impact, ft-lb.	80 to 65	45 to 35	5 to 1
Brinell hardness	125 to 150	170 to 210	275 to 350
Rockwell number	55 to 75-B	.....	<32-C

Temperature for slight oxidation ..... 570° F.
Annealing range (standard monel) ....1400 to 1800° F.
Forging range (standard monel) .....2150 to 1600° F.
Pouring range for castings .....2750 to 2900° F.

Cold-Rolled Sheet and Strip

TEMPER	SHEET		STRIP		APPROX. TENSILE STRENGTH
	SHORE	ROCKWELL B	SHORE	ROCKWELL B	
Dead soft	<16	<60	<16	<60	70,000
Soft	.....	.....	17 to 18	61 to 68	75,000
Soft skin-hard	17 to 20	61 to 73	.....	.....	.....
Skin hard	.....	.....	19 to 20	69 to 73	77,500
Quarter hard	21 to 24	74 to 82	21 to 24	74 to 82	80,000
Half hard	25 to 30	83 to 89	25 to 30	83 to 89	90,000
Three quarter	31 to 35	90 to 93	31 to 35	90 to 93	100,000
Hard	>36	>94	36 to 40	94 to 97	110,000
Full hard (strip)	.....	.....	>41	>98	120,000

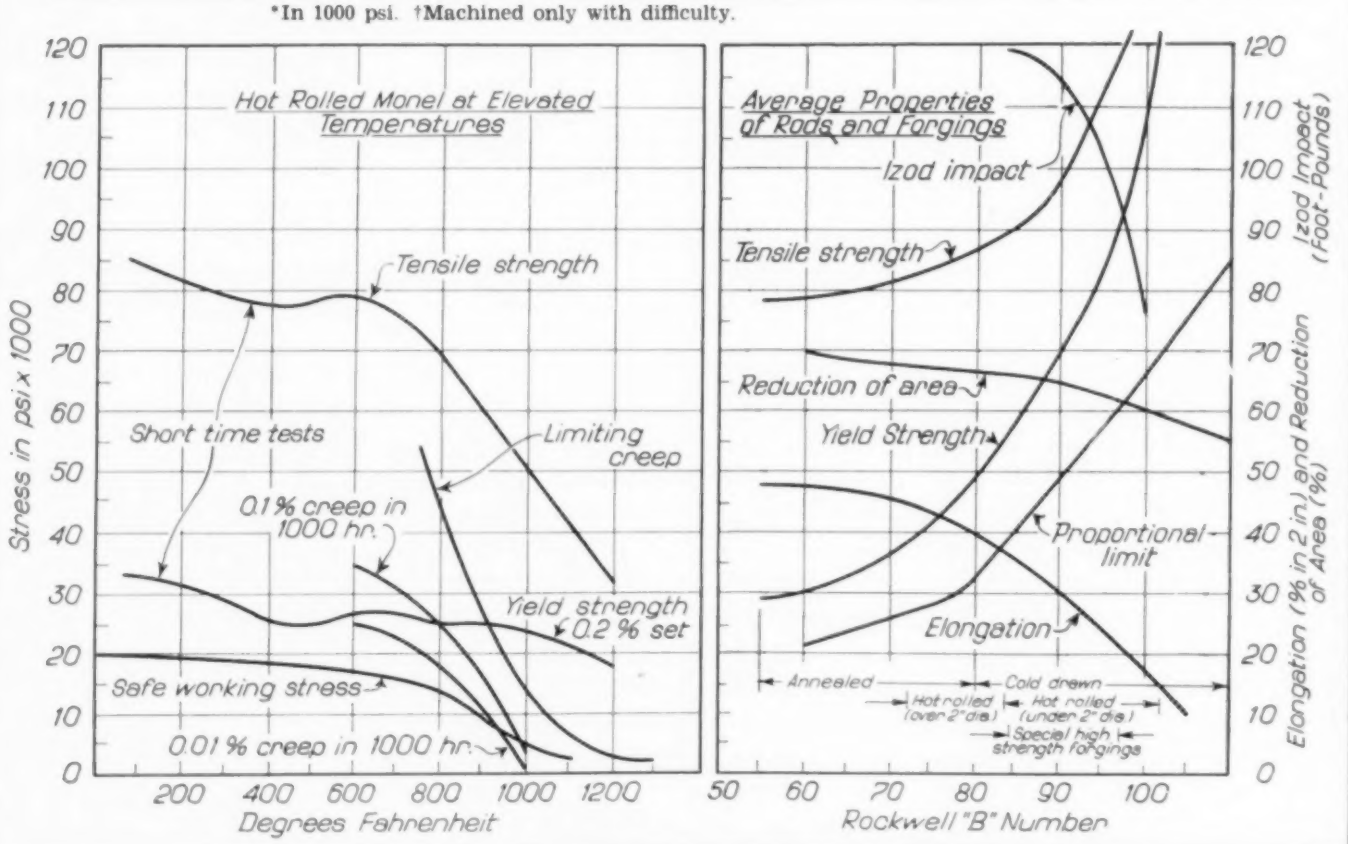
Physical Constants of Wrought Monel

Specific gravity 8.84
Density, lb. per cu.in. 0.319
Melting range
degrees F. .....2370 to 2460
degrees C. .....1300 to 1350
Specific heat at (80° to 212° F.)
(27° to 100° C.) 0.127
Heat expansion coefficient
at 80° to 212° F., per °F.....0.0000078
at 25° to 300° C., per °C.....0.000014
Thermal conductivity
at 80° to 212° F., B.t.u./sq.ft./hr./° F./in. 180
at zero to 100° C., cal./sq.cm./sec./° C./cm. 0.06
Electrical resistivity
at 32° F., ohms/circ.mil.ft. 256
at 0° C., microhms/cm.³ 42.5
Temperature coefficient of electrical resistivity
per ° F. 0.0011
per ° C. 0.0019
Modulus of elasticity
in tension, psi. 26,000,000
in torsion, psi. 9,500,000
Poisson's ratio 0.32

Mechanical Properties of K Monel

CONDITION	ULTIMATE*	YIELD (0.5% SET) *	ELONGATION	REDUCTION	BRINELL
Soft, quenched from 1450° F.	<120	<80	>40	>50	<225
Reheated to 1000° F.	120 to 140	80 to 100	>30	>35	225 to 275
Reheated to 1100° F.	140 to 160	100 to 120	>20	>25	275 to 325
Cold worked and reheated to 1100° F.	>160	>120	>15	>20	>325†

*In 1000 psi. †Machined only with difficulty.



Improved Foundry Practice

By H. H. Harris
President, General Alloys Co.

RESEARCHES of the Alloy Casting Research Institute at Battelle Memorial Institute and of the Chemical Foundation at Massachusetts Institute of Technology have been unusually fruitful, but they have as yet had little influence on the industry. The principal progress in heat and corrosion resisting castings has come from improved methods of heat treatment, inspection and finishing and better foundry practice:

1. Control over the gas content of the melt.
2. Control of grain size in the casting by controlling its pouring temperature and cooling rate, the latter by varying the capacity for heat absorption by appropriate portions of the mold.
3. Control of shrinkage and strain by various expedients — *(a)* "yielding" and "non-yielding" sections in the same mold; *(b)* pouring from two or more ladles of planned differences in temperature; *(c)* innovations in gating procedure.
4. Improved varieties of synthetic sands.
5. Use of semi-permanent molds.
6. Pressure casting to secure more uniform density than possible with conventional sand casting or centrifugal casting practice.

Many of these advances were utilized in casting the monumental plaque for the Associated Press Building, described in the May issue of METAL PROGRESS. They also have enabled us to achieve an outstanding service to the automotive and aviation industries in the alloy retorts, fans and other parts which are the "guts" of the radically new Leeds & Northrup vapo-carb and homo-carb carburizing furnaces. Batteries of these have been installed in the new air engine plants. Retorts up to 36 in. in diameter and 7 ft. long are made in ¼-in. wall section and have proved highly successful under the most severe service conditions to which alloy has been exposed.

Such recent notable progress was conceived and its main course planned long ago during depression years, but it could not come into being because price levels and consumer foresight were at a low ebb. Alloy manufacturers having greatly improved products to offer could not launch these improvements in a depression market where many buyers said, "We couldn't buy it if it was good, so why tell us about it?"

Despite the fact that alloy conveyor mechanisms of various proven designs have been commonly used in heat treating furnaces for many years, it is only recently that heavy loads have been handled. A most outstanding example is the Jamestown Malleable Iron Co.'s short cycle malleable furnaces built by Surface Combustion Corp., equipped with trays having six wheels, running on "hard" alloy bearings. These have been in service two years without alloy replacement.

Alloy conveyor designs are ready and waiting for loads up to 500 lb. per sq.ft., and can be most advantageously adopted in a properly heated furnace for shell annealing and the carburizing of armor plate. Despite the fact that many users and many able furnace builders, experienced principally in the heavier types of furnaces, are skeptical of heavily loaded alloy mechanisms, this writer emphatically states that most of the big jobs can be handled as easily with alloy mechanisms as the small ones. Progress in alloy engineering, thoroughly developed on a commercial scale, including such innovations as "hot" roller bearings and gear trains operating at 1800° F., is ready to serve the nation through vastly improved heavy furnace mechanisms.

Heat Resisting Castings
Medium Nickel Type

By Harrison I. Dixon
The Electro-Alloys Co.

THE PAST YEAR has seen little change in the manufacture of heat resisting alloy castings of more-or-less standardized types of analysis — medium nickel NC-4, or the 35% nickel, 15% chromium type, and the chromium-nickel CN-30 of 28% chromium, 12% nickel — a lack of news little missed in a world teeming with economic, military and political upheavals. Largely due to the rearmament program, as well as increased production of metal parts for industry, each type has had an extensive growth in tonnage.

Heat resisting castings today are subjected to service stresses and higher temperatures, never thought possible in the early use of alloys. Continuous and batch type gas carburizers require trays and fixtures to carry heavy loads of work from room temperature fairly rapidly to 1700° F. under reducing conditions, followed by complete immersion of fixture, tray and work in an oil or water bath; the cycle is then completed by a drawing furnace operation, at 900 to 1300° F., and tray and fixtures are reloaded.

Valves and Valve Seat Material

From paper by S. D. Heron, O. E. Harder and M. R. Nestor before American Society for Testing Materials

No.	Chemical Composition							Rockwell Hardness		Brinell Hardness, Hot (g)	
	C	Si	Cr	Ni	W	Mo	Other	Natural	After 1475° F. Draw	At 930° F.	At 1475° F
						Martensitic or Pearlitic Steels					
1	0.40–0.50	3.0 –3.5	8.0 –9.0	.	.	.		C–32 to 35	C–20 to 29	169–179	16–20
2	0.35–0.45	3.9 –4.2	2.8 –3.0	.	.	.		.		.	
3	0.50	1.5	8.0	.	.	0.75		.		.	
4	0.60–0.85	1.25–2.75	19–23	1.0 –2.0	.	.		C–38	C–31	254	26
5	1.0 –1.1	1.8 –2.0	13–14	0.75–1.0	3.25–3.75	0.50–0.75					.
6	1.27–1.43	<0.65	11.5–14	<0.65	.	0.45–0.95	2.5–3.5 Co	C–55			38 at 1600°
7	0.50–0.70	.	3.0 –4.0	.	12–16	.					
8	1.0 –1.2	<0.50	12–14	<0.50	.	.					
9	0.5	0.2	11.0	1.5	.	.	0.5 Mn. 1.8 Al				
10	2.5 –3.0	1.5 –2.0	2.75–3.25	.	.	4.0 –5.0	0.6–0.8 Mn				
11	1.0	1.0	25.0	.	.	.		C–40	C–19		28
						Austenitic Steels and Nickel-Chromium-Iron Alloys					
12	0.30–0.45	2.50–3.25	17.5–20.5	7.0–9.0	.	.		C–26	C–24	142	45
13	0.20–0.30	0.70–1.00	21–22	11–12	.	.		C–20 to 27	C–18 to 22	130–180	55–78
14	0.20–0.30	2.5 –3.0	21–22	11–12	.	.		C–24	C–20	166	71
15	0.40–0.50	0.30–0.80	13–15	13–15	1.75–3.00	<0.50		C–25	C–23	162	55
16	0.40–0.50	2.75–3.25	13–15	13–15	1.75–3.00	<0.50		C–30	C–22	165	53
17	0.50	1.25	14	26	3.5	.		C–22	C–16	182	84
18	0.40–0.50	0.30–0.80	24–26	13–15		2.0 –3.0		B–94	B–94		76
19	0.95–1.20	2.0 –3.0	15–16	13–15				C–24	C–30		94
20	0.50	1.0	20	32			1.0 Mn	C–21	C–19	174	80
21	0.50–0.60	0.50	3.5	12			5.0 Mn	C–22	B–95	140	55
22	0.10	0.30	14	80			.	B–83	B–83	107	54
23	0.07	<0.75	18	8			.	B–81	B–80	74	49
						Transformation Hardening Steels					
24	0.25–0.35	2.0 –3.0	12.0–13.5	7.0–7.75				C–42	C–41	244	98
25	0.40–0.50	<1.0	23.3–24.3	4.5–5.0		2.5 –3.5		C–41	C–36	230	63
						Non-Ferrous Alloys					
26	1.25	2.7	27	.	4		65 Co			217 at 1200° F.	132 at 1600° F.
27	2.0	0.9	30	.	12		54 Co			314 at 1200° F.	185 at 1600° F.
28	0.20	0.30	21	Balance		0.90 Mn	0.60 Fe				
29	0.16	0.02	30.3 Cu	66.9	0.16 Al	0.90 Mn	1.6 Fe				
30			Bal. Cu	.	9.5 Al		0.5 Fe				
31			Bal. Cu	4.0–6.0	10.5–11.5 Al		4–6 Fe				
32				>99.0							

No.	Scaling Loss (a)		Corrosion Resistance in Exhaust Condensate	Relative Attack by Lead Compounds (b)			Utility and Remarks
	Oxidizing Atmosphere	Reducing Atmosphere		$PbO \cdot PbBr_2$ at 1550° F.	PbO at 1800° F.	$2\,PbO \cdot 3\,PbSO_4$ at 1800° F.	
				Martensitic or Pearlitic Steels			
1	50	140	Poor	41	100	200	Most widely used exhaust valve material.
2	160	360	Very bad	41	106	258	Cheaper variety; inferior as to burning and rusting.
3	10,000	12,000	Very bad	.	.	.	Unsatisfactory substitute for No. 1.
4	40	75	Complete	1	104	8	Rapidly replacing No. 1.
5	.	.	Very bad	.	.	.	Limited use replacing No. 6.
6	5,000	2,200	Very bad	16	136	6	Superseded No. 7 for aircraft use in early 1920's.
7	—	—	Very bad	—	—	—	High speed toolsteel; adopted in U.S. in 1911; much used in War; first valve with good hot strength.
8	19,000 (c)	19,000 (c)	Very bad	56	64	3	Cutlery stainless (modified); used in Europe for 1916-1918 aircraft.
9	.	.	(d)	26	113	5	Reputation for unreliability in automobiles.
10	18,000	17,000	.	36	240	520	Cast exhaust valve seats for passenger cars and trucks.
11	60	100	Complete	2	14	1	In experimental use.
				Austenitic Steels and Nickel-Chromium-Iron Alloys			
12	90	70	Complete	63	57	46	Wide use in automobiles for its hot strength.
13	30	60	Complete	37	43	2	Wide use in bus and truck engines.
14	50	90	Complete	48	48	17	Higher silicon than No. 13 does not improve resistance to burning.
15	2,600	1,600	(e)	20	126	26	U.S. aircraft exhaust valves; internally cooled and seat faced.
16	100	150	Complete	25	92	184	Too hard to drill; seat inserts in aluminum cylinders.
17	840	370	Complete	28	73	228	European aircraft exhaust valves.
18	50	40	(e)	12	47	0.3	Recently introduced to replace No. 15; about same in severe service; no intergranular attack by sodium.
19	140	160	Complete	.	.	.	Castings for both intake and exhaust valves on Ford motors.
20	60	40	Complete	.	.	.	Limited use, as cast, in auto, bus and truck valves.
21	11,000	11,000	(d)	.	.	.	Exhaust valve seats in European aircraft. High thermal expansion requires threaded design to remain tight.
22	60	50	Complete	40	42	254	Not used, despite interesting properties.
23	2,400	1,700	Complete	25	112	2	Not used, despite interesting properties.
				Transformation Hardening Steels			
24	2,800	2,300	Very good	49	81	24	Had limited use in autos and wide use in aircraft.
25	40	50	Complete	2	35	1	Better wear and scuffing resistance than austenitic steels; embrittled by many cycles between 1400 and 1600° F.
				Non-Ferrous Alloys			
26	20	15	Complete	0.5	4	0.5	Stellite No. 6; almost universal in U.S. for welded-on seat facings in aircraft engines.
27	50	15	Complete	72	6	1	Valve seat inserts for bus and trucks, with higher hot hardness and wear resistance than No. 26.
28	45	15 gain	Complete	71	52	197	Brightray; used in Europe for welded-on seat facings.
29	13,000	30	Very good	.	.	.	Monel; used in Europe for some exhaust valve seat inserts.
30	1,000 (f)	.	Good	100	244	243	Formerly much used as extruded valve seat inserts in aluminum cylinders.
31	.	.	Good	.	.	.	Cast and heat treated substitute for No. 30. Neither good for leaded fuels.
32	250	70	Complete	3	340	504	Commercially pure nickel; has unusually high hot corrosion resistance.

Notes: (a) Loss in mg. on ⅜x2-in. rod after 300 40-min. cycles between 1800° and 650° F. Fuel is a special kerosene with anti-knock additions, burned with 15½ lb. air per lb. for oxidizing atmosphere and 12½ lb. for reducing. Low results may be misleading

(b) Calingaert test. Relative loss after 6 min. in molten compound.

(c) After 250 cycles.

(d) Probably very bad.

(e) Complete if not nitrided; poor when nitrided.

(f) Maximum temperature on heating cycles: 1600° F.

(g) By mutual indentation.

While the quenching operation produces little change in the microstructure of the austenitic alloys, the continual exposure to oxidizing or reducing conditions, or both in turn, produces incalculable stresses in castings, sometimes resulting in failure from premature cracking. The use of various types of alloy additions, such as titanium, vanadium, columbium, or nitrogen treated ferrochrome, has helped but not eliminated these troubles. More attention to the quality of raw materials, condition of mold and core sand and X-ray inspection is producing castings with fewer internal as well as external defects, and a resultant longer life.

The 29-9 chromium-nickel type of alloy casting, 0.20 to 0.30 carbon, has shown good corrosion resistance in the as-cast condition, without the use of a stabilizer such as titanium, as compared to the low carbon 18-8 type in similar applications. Fabricated alloy sheet and cast "combination" carburizing boxes have been improved by introducing a "tongue and groove" type of flexible joint for top and corner pieces, thus allowing a free movement of the side wall and resulting in less cracking and deformation. Castings of high chromium-iron alloys with minor nickel and low carbon (28% Cr, 1% Ni max.) are now operating as container and electrode at 2300° F. in electrically heated salt baths for hardening high speed steel. Casting life in such installations, where temperature is not too intermittent, now approximates six months.

Physical properties of the 24% Cr, 12% Ni and the 35% Ni, 15% Cr types, as shown by the Alloy Casting Research Institute and quoted in METAL PROGRESS in October 1939, page 553, indicate higher ductility for 35-15 alloy, after prolonged high temperature exposures, with little loss of mechanical strength. This is of special importance to furnace castings (except where sulphur is present, which requires the use of 24-12, due to sulphidation of high nickel type alloys) inasmuch as cracks from heating and cooling stresses are apparently resisted by the increased ductility found in 35-15.

High Nickel-Chromium Castings

By Joseph B. Shelby
Manager, Foundry Dept., Driver-Harris Co.

IN THE TEMPERATURE RANGE between 1300 and 2100° F. the industry has centered on three predominating analyses. They are 60% nickel, 13% chromium; 35% nickel, 15% chromium; and 12% nickel, 26% chromium. In all of these the balance is iron plus the important ingredients of carbon, silicon, manganese and minor alloy additions. While this variety would seem to provide a convenience in the foundry, yet even these representative analyses must be varied in minor ingredients to be suitable for particular applications, and it is this selection which imposes so much responsibility on the designer and foundryman.

Gas carburizing has clearly shown itself to be one of the most difficult applications for alloys to withstand, and most frequently this is complicated by the supplementary operation of an oil quench. The mechanism of failure of alloy parts in gas carburizing by erosion or corrosion is not yet fully understood but representative foundries have learned to control it, and a great improvement in life under these circumstances is assured. The most severe service arises where the alloy is completely surrounded by the gas, as is the case when baskets, trays or fixtures are used in muffles and retorts.

Of great importance now to the carburizing, nitriding and heat treating fields is the economical loading of a furnace to get the greatest production. The full cooperation of all concerned has frequently resulted in doubling the load in a given furnace. This accomplishment has resulted from interesting designs requiring castings, rod, tube, sheet and welding of high alloys.

The position of the alloy casting industry as regards national defense is indirect, but our greatest outlet is to industries engaged in defense work. Since the inception of these alloys, their uses and limitations have been studied and improved, and today they offer means of doing things faster, thus being a contribution towards increased production of mechanisms unequaled by any other single factor. They make today's furnaces possible.

Even with this tremendous importance attached to their use, the true worth of these alloys is not always developed. The "heat-hour" cost of use in service is the only true denominator and not the first cost or purchase price. When this fact is studied, it leads to real economy. "Nominal analysis", usually designating only the nickel and chromium in the alloy, is not indicative unless melting and molding practices of the competing foundries are identical. Where sulphurous gases are not present, as is the case in the large majority of high temperature applications, a study of heat-hour costs will demonstrate the economy of the higher nickel alloys.

THIS CLOCK ALL Q-ALLOYS CASTINGS
KEPT TIME AT 2000° F.
AT 1928 STEEL SHOW AT PHILADELPHIA
ABRAHAM LINCOLN 28" BAS RELIEF AS CAST
OF COURSE IT RINGS LIKE A BELL! A Q-ALLOY CASTING
CAST HEAD IN S. S. FROM LIFE BY ISAMUNAGUCHI
Q-ALLOY CAST MICROMETER FRAME
DOORS DESIGNED AND EXECUTED BY OSCAR BACH G. A. CASTINGS
UNEQUALLED EQU
These highly diverse castings are shown to strengthen your conviction that there is no substitute for experience and—if you know alloys—that General Alloys has no quality competition.
OIL STILL TUBES HANG
VACUUM PUMP ASSEMBLY
GENERAL AL
ELECTRICAL HEATING ELEMENT
PERMANENT MOULDS
SETS THE STANDAR
FINE DETAIL
PUMP PARTS
2800 LB. POLISHED ROLL
MARBLE CONVEYOR FOR 2150° F.
HOT ROLLER BEARING ROLLS
CARBURIZING BOX AND TRAY
CYANIDE
U. S. NAVY STAINLESS STEEL PORTHOLES
CASTINGS FOR THE PROCESS INDUSTRIES
A 5600 LB. ASSEMBLY
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PLAQUES ON THE
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"TRICK" CASTINGS
ARE OUR MEAT

CHRYSLER BUILDING
10" HIGH IN
Q-ALLOY

CAST TUBE 14 FT. LONG

CUTS EASILY

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600 LB. PIECE

CHEMICAL PIPING

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CAST CLOCK FACE

"KLOIZENAY" FUSED GLASS
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A COMPLETE LINE OF
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HINGED FURNACE TRAY (PATENTED)

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ROLLER RAILS
(3 MILES IN SERVICE)

X-HE RETORT CASTINGS FOR
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YOU NAME THIS ONE

30,000 patterns and *more* comprise the foundry experience of the oldest and largest exclusive manufacturer of heat and corrosion resistant castings.

The casting of complex alloys is still more an art than a science and General Alloys' New England craftsmen excel in that art as General Alloys' engineers and metallurgists excel in alloy technology.

A MICHIANA SUGGESTION MAY SAVE YOU TROUBLE, TOO

MAKING so wide a variety of alloy castings —studying these applications and checking performance has given MICHIANA a storehouse of experience of value to all users of heat- and corrosion-resistant alloys.

Difficulties Eliminated — Costs Reduced

Frequent breakages of heat-resistant alloy chains in heat treating furnaces brought MICHIANA in to investigate the costly difficulties.

Correction had been attempted by increasing the chain weight, but a study of all the factors disclosed the fact that the sprocket designs were the cause of the trouble. With redesigned sprockets, much lighter and less costly MICHIANA alloy chains proved satisfactory and frequent breakages and production delays were eliminated.

Consult MICHIANA on Alloy Castings

This typical case is cited to illustrate our policy of cooperation. Nearly a quarter-of-a-century specialized experience is at your service . . . A MICHIANA suggestion before the work is started may save valuable time, expense and trouble later.

You can place your requirements with MICHIANA with full confidence of thorough handling from receipt of specifications and prints to the finished castings.

Visit our Booth H-25
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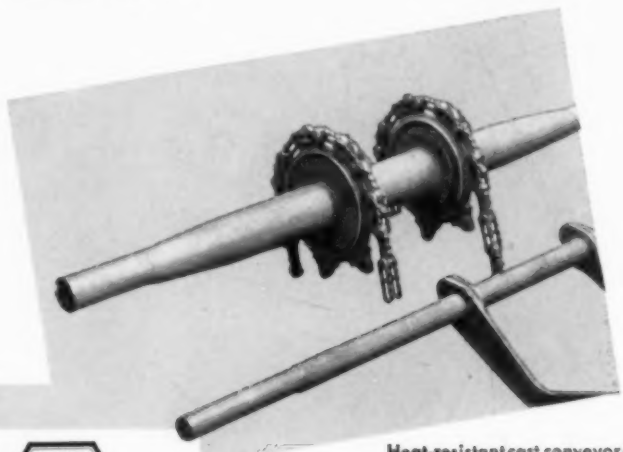
MICHIANA PRODUCTS CORPORATION
MICHIGAN CITY **INDIANA**



Heat-resistant cast conveyor chain, with sprockets and shafts also of heat-resistant alloy—for a continuous heat-treating furnace.

MP CORP.

Retorts • Rails
Pots • Boxes • Grids
Sprockets • Chains
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Heat-Resistant and Stainless Steel Alloy Parts of all kinds.

MICHIANA
Heat-Resistant and Stainless Steel
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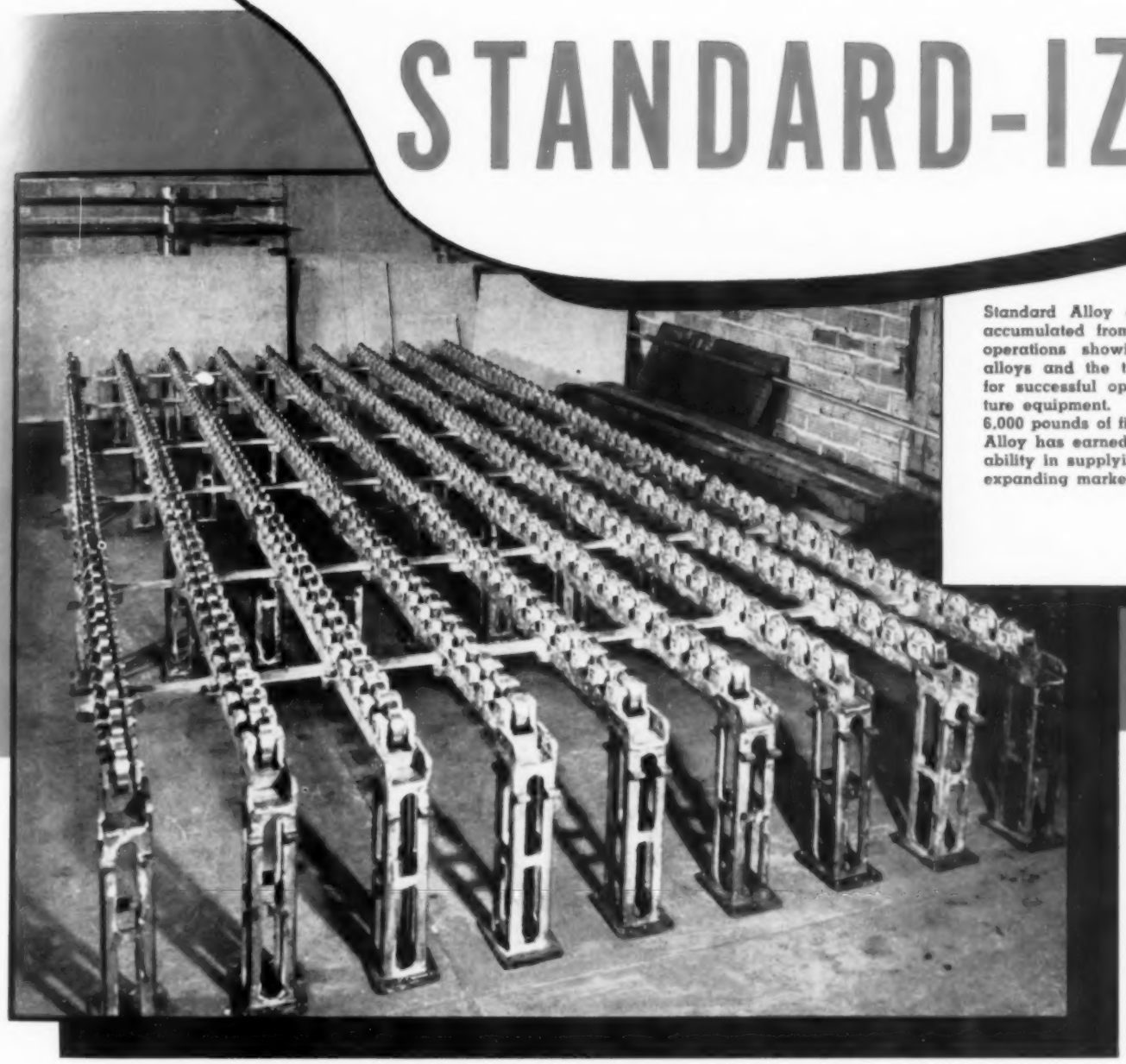
IF YOU USE FURNACE PARTS

Don't Experiment--

STANDARD-IZE



Standard Alloy offers a wealth of data accumulated from many tests and actual operations showing the compositions of alloys and the type of design necessary for successful operation of high temperature equipment. With a daily capacity of 6,000 pounds of finished castings, Standard Alloy has earned a reputation for dependability in supplying quality castings to an expanding market.

Beating heat and corrosion is the every-day task of the Standard Alloy Company. The nickel-chromium heat resisting cast roller rails shown above are successfully overcoming the heat and corrosion problems encountered in the heat treating furnace of a large industrial plant.

Standard makes a specialty of jobs like this—nickel chrome alloy castings that resist heat and corrosion WELL. In the last twelve years we have manufactured many thousand items of this metal—everything from carburizing boxes to large pieces like the roller rails above.

If you have a heat and corrosion problem, call a Standard engineer. He'll be glad to work with you in licking the most difficult problem.

STANDARD ALLOY COMPANY, INC.

1679 COLLAMER ROAD CLEVELAND, OHIO

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Towle & Son, 18 W. Chelten Ave. Bldg., Philadelphia, Pennsylvania.

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Standard Alloy Company, DETROIT OFFICE, 2970 W. Grand Blvd., Detroit, Michigan.

STANDARD *Heat-Resisting* **CASTINGS**

NICKEL CHROME ALLOY

Decorative Stainless Steel

(Continued from page 461)

However you choose to define the "decorative" field of stainless steel, it is almost immeasurable in scope. It is safe to say that there is no sizable building erected today which does not make generous use of stainless steel somewhere in its interior or exterior details. The same holds true for modernizing operations on old structures.

Building construction is just one industry in which the eye-appeal of stainless has won favor. Transportation, and the broad metal working and mechanical industries are others. Our automobiles, busses, trucks, trains or planes shine with stainless appointments. In trucks and trains stainless has gone on from decorative details to vital structural members.

In the metal working and mechanical industries, producing such articles as metal furniture, house furnishings, toys, utensils, electrical appliances and a vast category of similar products, stainless steel appears in greater profusion each succeeding year. Some manufacturers make their products wholly from it, some use it merely for trim; but their common experience is that articles so made *sell* better, not only because their looks are improved, but their lasting qualities as well.

There are also a veritable host of decorative applications where the prime requisite — aside from sheer beauty — is that stainless gives patrons an impression of complete sanitation, and bears out the impression by actually making sanitary measures both easier and cheaper. Under such conditions, stainless is a "must" — and almost any modern restaurant, food store, soda fountain, bar or cocktail lounge would supply ample proof.

In general, the decorative and (since they're really inseparable) the utilitarian uses of stainless steel have found only two factors that tended to retard their growth — first is the relative expense of solid stainless, as compared to plated metals or to enameled steel, and second is the occasional difficulty in fabrication except by skilled workers.

Both of these retarding influences have been largely swept aside with the advent of "Ludlite Bord" (made in rigid panels of standard wallboard sizes) and "Ludlite Flex" (supplied in sheet and tile forms). Both these forms consist of a thin surface of 18-8 combined under pressure with inert backing materials. Their variety of form and finish, their adaptability both to interior and exterior work, and above all, the fact that they work as easily as common building materials and can be handled or installed by ordinary workmen, combine to give them the greatest potentialities of any product introduced in recent years. They justly deserve the term "Everyman's stainless steel".

Annealing Cover for steel mill use. Made of Lightweight Alloys to any specifications.

"Lightweight and long in Service"

Carburizing and Annealing Boxes

by

THE PRESSED STEEL COMPANY

. . . reduce heat-treating cost. They offer stubborn resistance against heat-corrosion and hard service. In spite of their light weight these products have the capacity to stand up under the most severe operating conditions, and in most cases, will outlast cast alloy boxes weighing three times as much.

Photograph of Annealing Cover used in steel mills. Made of alloys to suit your specifications. Any size. Any shape.

THE PRESSED STEEL COMPANY

WILKES-BARRE, PENNSYLVANIA

Pressed Steel Company Products: Carburizing and Annealing Boxes, Thermocouple Protection Tubes, Seamless Steel Cylinder Caps, Seamless Steel Neck Rings, Welded Alloy Tubing for High Temperature and Corrosive Application.

UNIFORMITY

at HIGH temperatures

Uniformity, metallurgically and in performance, is essential when repetitive castings are made in a foundry. Repetitive castings made by Driver-Harris Company assure precisely the same casting from year to year.

The Driver-Harris Engineers have been trained in a school of uniformity so vital in the production of accurate alloys for different applications in the heat treating and electrical fields.

The same care goes into the making of Driver-Harris Foundry products as is used in the making of one mil wire, for which "Nichrome" and uniformity have become synonymous.

These engineers skilled in the school of experience and uniformity are prepared to design and work out equipment to suit your needs, ever mindful of assuring endurance and commercial economy.

When uniformity counts call a Driver-Harris Engineer.

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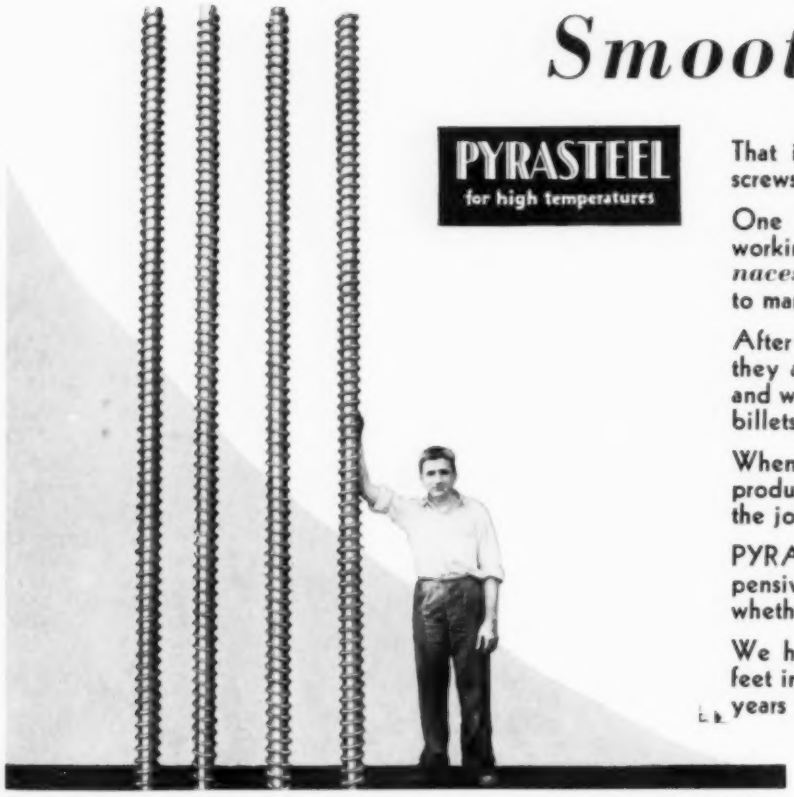

PYRASTEEL
for high temperatures

That is the only way to describe the PYRASTEEL screws which we are making for heat-treating furnaces.

One of the essential requirements of these screws, working at high temperatures *in heat-treating furnaces*, is that they shall be perfectly smooth, so as not to mar the stock.

After they are cast and cleaned in the ordinary way, they are ground and polished to a mirror-like surface, and will handle such delicate materials as round copper billets without marring the surface.

When material is to be conveyed in containers, we produce screws smooth enough *in the rough* to do the job.

PYRASTEEL screws are the most efficient and inexpensive way of conveying a charge through a furnace, whether in separate pieces or in containers.

We have installations of continuous screws up to 32 feet in length which have been in operation for several years without failure or any interruption of the service.

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CHICAGO STEEL FOUNDRY COMPANY
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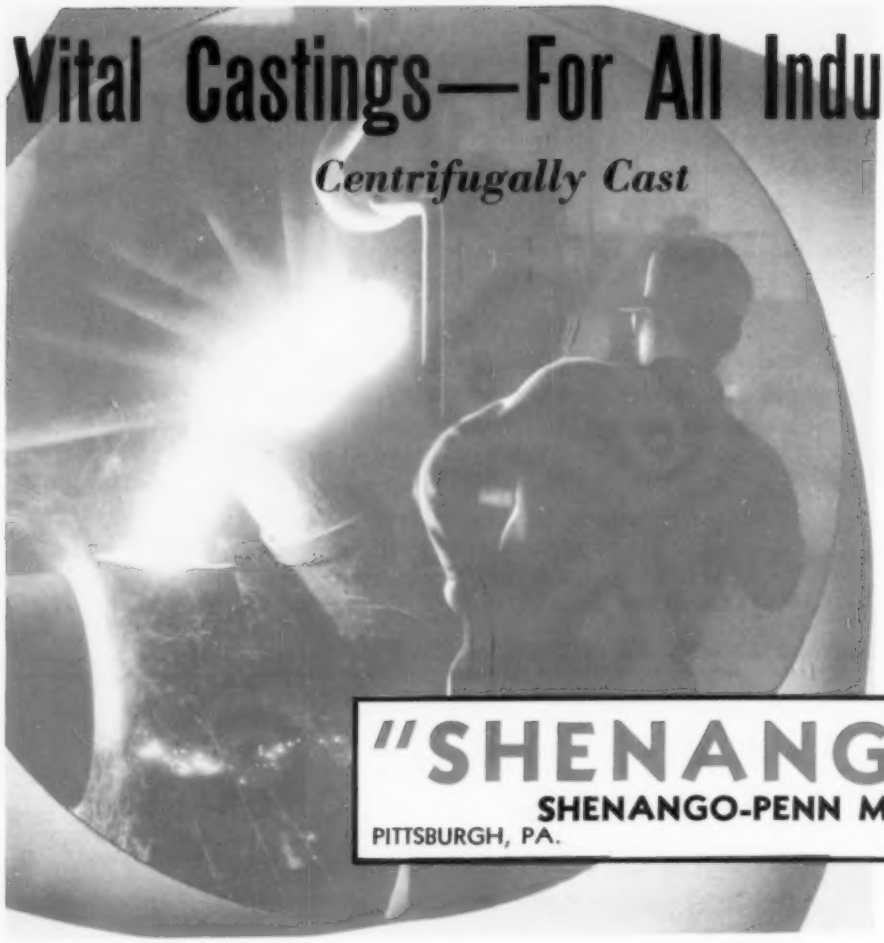

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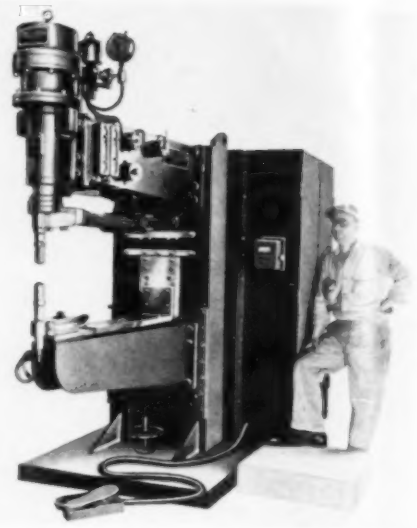
Spot Welder

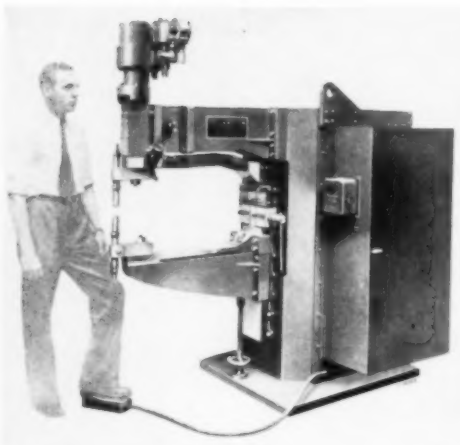
(120 KW)
PMCO. 3S



Capacity in 1/1000 inch
Aluminum
.020″ plus .020″
up to
.160″ plus .160″

Spot Welder

PMCO. 2S
(40 KW)



Capacity in 1/1000 inch
Aluminum
.020″ plus .020″
up to
.080″ plus .080″

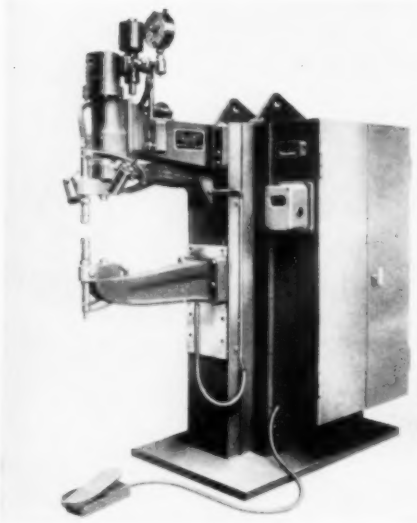
Spot Welder

PMCO. 1S
(25 KW)

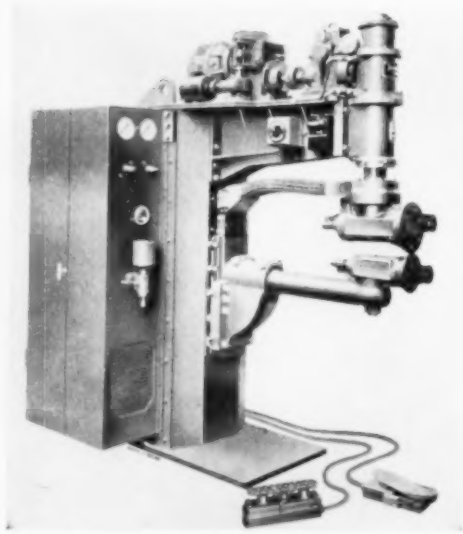
Seam Welder

PMM. 2 (350 KVA)

Upper Wheel Circumferential
Speed from 1'6″ to 19'2″ ft./min.



Capacity in 1/1000 inch
Aluminum
.012″ plus .012″
up to
.050″ plus .050″



Capacity in 1/1000 inch
Aluminum
.020″ plus .020″
up to
.080″ plus .080″

Lockheed Aircraft Corp.
Curtiss Aeroplane Division
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Boeing Aircraft Company
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Stearman Aircraft Corporation
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"Sciaky Welds Aluminum Thin and Thick"

See us at the Metal Show Booth A-34

Welding and Cutting

Welding of Aluminum

By G. O. Hoglund
Aluminum Co. of America

AN INCREASED USE of aluminum and aluminum alloys has given impetus to the development of automatic methods for welding them. These are concerned primarily with arc welding and electric resistance welding, and with a new method for assembly by brazing.

The first application of automatic arc welding used the carbon arc for assembling aluminum alloy tank cars. The equipment superimposed an a.c. field around the arc, and this method has been used in production on metal up to ⅝ in. thick, with substantial gain in speed over the manual gas welding. The soundness and strength of the welds are superior, and the amount of distortion in the tanks from the welding operation has been reduced. The result is better tank cars at no increase in cost, and it seems likely that an eventual lower cost will be attained.

The wider use of electric resistance welding is becoming apparent in fabricating aluminum alloy aircraft parts, because this method is more economical and can be adapted to the production of large numbers of similar parts. It is possible, in addition, to make spot welds on parts exposed to the air stream without disturbing the smooth surface which is essential from the aerodynamic standpoint on high speed aircraft.

The high currents necessary for spot welding aluminum have been attained by energy storage methods which supply adequate welding current with about 25% of the peak load requirements that have been necessary on standard a.c. spot welders. This factor is particularly important in view of the comparatively large number of units which are now required to produce aircraft parts on a production basis. Improved soundness of the welds, as well as improved unit strength of welds in the various alloys, has been achieved. Some problems remain to be solved to permit the use of spot welds most efficiently in structural parts. From lack of specific information, spot welded joints have been designed on the basis developed for riveted joints. This does not result in the most efficient use of welds, and added experience is rapidly being obtained to establish proper design rules.

Four or five years of experience and service is now available and the record of spot welded parts has been very good. No service difficulties have occurred on several thousand airplane tanks during this period. This is also true of spot welded parts which have been used in the refrigerator, cooking utensil, marine, and railroad fields.

The production use of brazing methods on the aluminum alloys has been extended during the past year. Laboratory investigation has established that their resistance to corrosion is comparable to that of welded joints, and that the strength (particularly on the magnesium-silicon-aluminum alloys suitable for brazing) is actually higher than welded joints. Batch brazing of outboard motor tanks has been applied in production to over 100,000 units. Costs have been substantially reduced. The process has also been useful for assembling shelves, evaporators, refrigerant lines and miscellaneous parts on refrigerators.

Fusion welding in the form of gas welding and metallic arc welding has found extended use on the aluminum alloys during the past year. Something over 200,000 beer barrels have been assembled by gas welding. Metallic arc welding has widened its scope of applications, although no new developments changing the process have appeared.

Cooperative Welding Research

By Comfort A. Adams
Consulting Engineer
Chairman, Welding Research Committee
of the Engineering Foundation

RESEARCH may be divided into two types, and they may be distinguished chiefly by their main objectives:

1. *Fundamental Research:* I am giving this name to that type of research, the chief object of which is to develop a more thorough understanding of the phenomena involved — that is, the "reason why" — and to fill out the skeleton of theory which will aid in the more rational solution of many more problems, not only in the same but often in widely different industrial fields.

2. *Industrial Research;* This usually consists in getting answers to specific problems in the shortest possible time without much reference to the reason why. In fact, in some cases the time limitations are such that no really satisfactory solution can be found and it is necessary to accept the best makeshift available. Even under favorable conditions, as soon as an answer is obtained which is satisfactory for the immediate purpose, the subject is usually dropped without any attempt to understand the reason why, or to fit the otherwise empirical information into the skeleton of theory.

This custom which is generally prevalent in industrial research is not always due to a lack of desire to understand the reason why, but rather to the pressure and drive of our industrial system. However, it is sometimes due to a lack of a thorough grasp of the underlying scientific principles, to a lack of a working familiarity with the necessary mathematics, or to a lack of the analytical habit, the instinctive desire to know the reason why.

All this is peculiarly true in the field of welding, where the problems involve an unusually large number of the fields of science, and are often so complicated as to scare off all except a very few who have both the desire and the scientific background necessary to attack the problem by the scientific method.

The number of significant variables involved in some of these welding problems is so great that anything approaching a reasonably exact scientific solution is absolutely impossible. Nevertheless a really intelligent attempt often so clarifies our perspective, both qualitatively and quantitatively, as to indicate clearly the best method of experimental approach and thus greatly simplify the experimental work. It also increases the prospect of a broader and more rational application of the results obtained.

A very pertinent and timely illustration is the rate of cooling of the metal in the weld zone and its relation to the microstructure and physical properties of the products of transformation, as well as to the residual stresses. This problem, usually covered by the term "weldability", is probably the most vital one before the welding industry today.

The best method of illustrating the difference between the two methods of attack is to present two pictures illustrating these methods when applied to the weldability research:

1. *Rational Method.* The investigators will first attempt to determine the relationship of the rate of cooling to the several variables involved, the major of which are the amount of heat delivered to a given zone, and the heat dissipating power of that zone. The latter is in turn dependent upon the specific heat and thermal conductivity of the material, the geometry of the region involved, the base temperature and the surface conditions. For example, the rate of cooling is considerably retarded by a slag coating resulting from the use of certain types of covered electrodes. It is even more retarded by a blanket of dry powder, such as provided in the Unionmelt process.

A reasonably satisfactory mathematical solution of this problem is too complicated for even high grade mathematical physicists. Nevertheless, with the necessarily crude approximations, a quantitative perspective can be obtained. Moreover, a fairly simple but rational formulation can be developed with the aid of coefficients and exponents which can be determined experimentally for a few typical cases.

In other words, if this method were employed, the result would be not only a far better understanding of the influence of the several variables but also the ability to predict with a fair degree of accuracy the rate of cooling under new combinations of the various factors involved. At the present time, the lack of real information is such that quantitative thinking on this subject is quite impossible.

After some information on the rate of cooling is available, the next step is to determine its relation to the products of transformation — that is, to the microstructure of the weld zone. More specifically what is required is the determination of the critical rate of cooling for

a number of typical compositions. (By "critical rate" is meant that rate above which the microstructure is such as to result in serious danger of cracking. This microstructure is usually referred to as martensitic, as it contains more or less hard and brittle martensite.)

Some information is already available on this subject for a few varieties of steel and although the methods thus far employed for this purpose are very laborious, simpler methods are now available which will probably yield satisfactory results.

Finally, the relation of the residual stresses to the rate of cooling is an even more complicated problem. In fact, there is probably no field of analysis in connection with which the average engineer is so apt to go astray. The cooling of metal in the weld zone is always accompanied by multi-axial stresses, concerning which our present knowledge is exceedingly limited. Nevertheless, a few fundamental facts or relationships have been pretty thoroughly established. Although the mere statement and explanation of these facts is far beyond the scope of this review, one of the most significant, as bearing on the present problem, is that the resulting stress gradient (and therefore the magnitude and danger of the residual stress) is roughly proportional to the rate of cooling. In other words, there is probably a critical rate of cooling for each type of steel, above which residual stresses are in the danger zone, particularly for structures subject to impact or to pulsating stresses. In any case, there is certainly a critical rate of cooling for each type of steel above which the effect on the microstructure in combination with the residual stresses is in the danger zone.

Thus, if we could determine experimentally this critical cooling rate for each type of steel, and develop an analytical method of predicting the cooling rate by means of rational formulas with experimentally determined constants, we would be in a vastly stronger position than if we were to follow the more empirical method to be described below.

2. *Empirical Method.* In any attempt to determine experimentally the quantitative relationship between a result and a number of variables, the number of experiments necessary increases in geometric proportion to the number of variables involved, and soon becomes prohibitive even when the number of variables is much less than in the weldability problem under discussion.

Moreover, our present knowledge of the relative importance of these variables is not sufficient to serve as a basis for the selection of the few of major importance. Even if this were possible, the results when plotted would constitute what is commonly known as a "shot gun diagram", and very difficult if not impossible to interpret intelligently.

In other words, in order to make this empirical method really serviceable it would be necessary to multiply the number of experiments far beyond the limits of possibility from the standpoint of either time or cost. If, on the other hand, we pick a feasibly small number of the major variables, the results are sure to be of very limited value and possibly misleading.

It is on this account that I am convinced of the great superiority of the more rational method of attack. . . . .

Although I have used a single illustration to emphasize the major point at issue, the same considerations apply to scores of other cases.

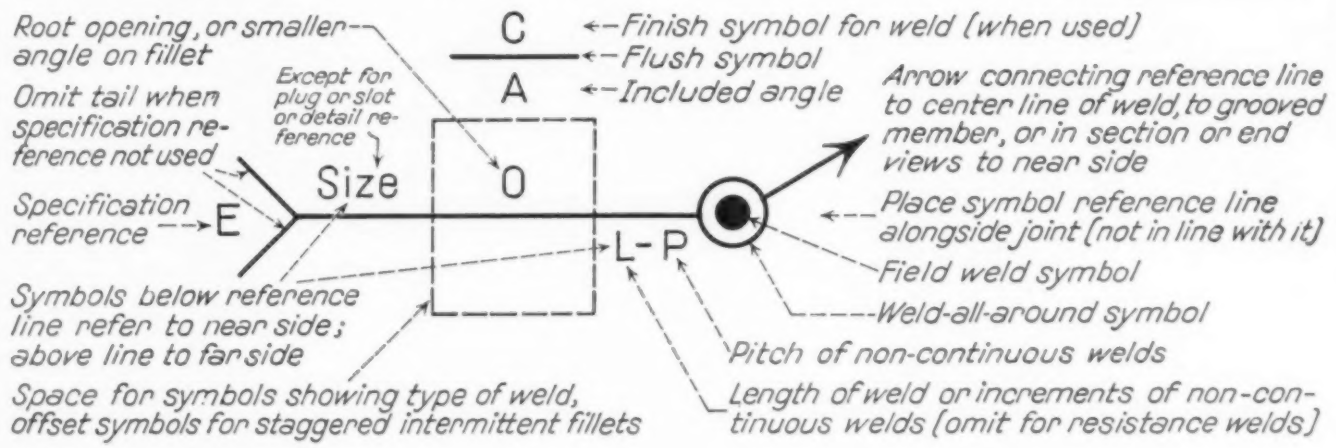
My interest in cooperative research is two-fold. First, it means a very great reduction in the cost to industry as a whole, and second a greater prospect, through the cooperation of many types of mind, of a rational attack and of results, not only more dependable but also more far-reaching in their application. It also encourages a very valuable interchange of experience between industrial engineers and contributes in no small part to their education and usefulness. Because of the over-emphasis of the competitive spirit, the development of the cooperative spirit has been slow. Nevertheless, the progress has been steady and the Welding Research Committee of the Engineering Foundation (sponsored jointly by the American Welding Society and the American Institute of Electrical Engineers) is now collecting about $50,000 a year from industry, the number of subscribers having approximately doubled during the past year.

Welding Symbols

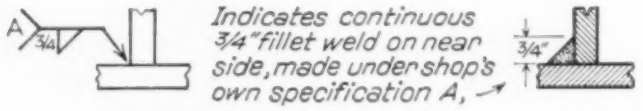
Adopted as Standard by American Welding Society, 1937

For Fusion Welding								For Both			For Resistance Welding			
Type of Weld											Type of Weld			
Bead	Fillet	Groove					Plug & Slot	Field Weld	Weld All Around	Flush	Spot	Projection	Seam	Butt
		Square	Vee	Bevel	U	J								

Standard Location of Information on Welding Symbols

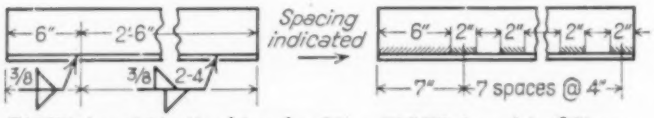

Root opening, or smaller angle on fillet
Omit tail when specification reference not used
Except for plug or slot or detail reference
Specification reference
E
Size
C
Finish symbol for weld (when used)
Flush symbol
A
Included angle
0
L-P
Arrow connecting reference line to center line of weld, to grooved member, or in section or end views to near side
Place symbol reference line alongside joint (not in line with it)
Field weld symbol
Weld-all-around symbol
Pitch of non-continuous welds
Length of weld or increments of non-continuous welds (omit for resistance welds)
Symbols below reference line refer to near side; above line to far side
Space for symbols showing type of weld, offset symbols for staggered intermittent fillets

Significance of Typical Combinations



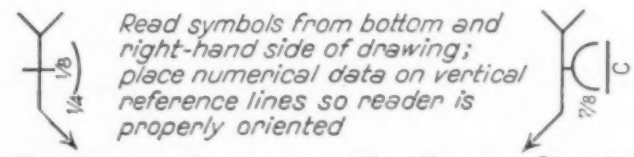
Indicates continuous 3/4" fillet weld on near side, made under shop's own specification A,

Significance: Weld all around (encircling member as far as possible). Near side: 1/2" fillet, 2" long, 5" on centers. Far side: plate has 3/4" J groove (shop's standard), continuous weld



3/8" fillet weld both sides for 6". Welds on both sides are same size unless noted

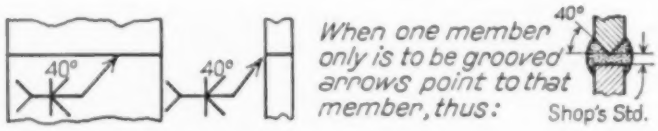
3/8" fillet welds 2" long, 4" on centers, opposite sides staggered



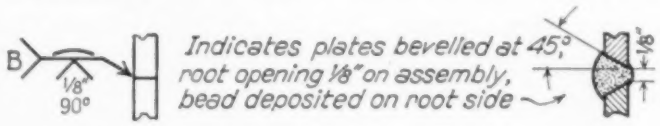
Read symbols from bottom and right-hand side of drawing; place numerical data on vertical reference lines so reader is properly oriented

Significance: Square edges on plates clearing 1/8", welded from near side, 1/4" penetration required

Significance: Closely abutting plates with U groove 7/8" deep, near side chipped smooth

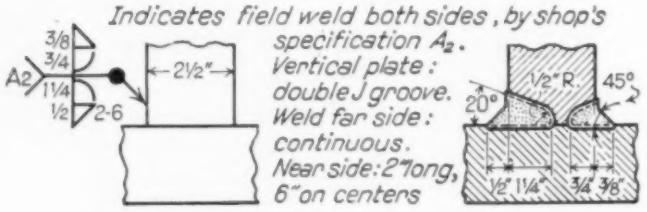


When one member only is to be grooved arrows point to that member, thus:

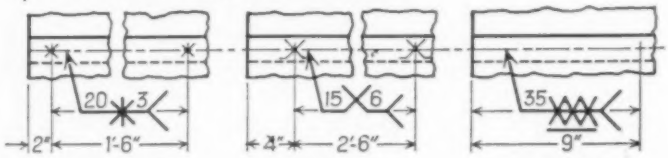


Indicates plates bevelled at 45°, root opening 1/8" on assembly, bead deposited on root side

Symbols govern to break in continuity of structure or to extent of hatching or dimension lines. Strength of resistance welds in hundreds of pounds noted instead of size:



Indicates field weld both sides, by shop's specification A_2. Vertical plate: double J groove. Weld far side: continuous. Near side: 2" long, 6" on centers



2000-lb. spot welds, @ 3" centers

1500-lb. projection welds @ 6" centers

3500-lb. seam weld, 9" long, flush near side

For other combinations see "Welding Journal", June 1937

Cutting and Surface Conditioning

By Herman Ullmer
Manager, Process Service
The Linde Air Products Co.

AN OUTSTANDING RECORD of progress has been made in the application of the oxy-acetylene processes known as deseaming, gouging, descaling, and flame cleaning. Another noteworthy development has been the special adaptation of the cutting blowpipe for steel cut-off operations in the steel mills.

One of the most spectacular recent developments has been the use of the flame for removing surface defects from semi-finished steel. Specially designed deseaming blowpipes "wash off" sections of the surface that contain the imperfections. Sufficient steel in the vicinity is removed to eliminate the defect itself and leave clean, sound metal with acceptable contours for further rolling or forging. Hand deseaming is usually done on cold slabs and billets. For hot metal, special oxy-acetylene machines have been fitted into the rolling mill tables and clean all four sides of the bloom or billet simultaneously, thus speeding the production of steel with perfectly sound surface.

Development of the oxy-acetylene gouging process has resulted from a growing need for quick and cheap removal of metal from the underside of electric arc welds, for removing defects revealed by inspection, and for grooving of plate edges in preparation for welding. While the process is still in its infancy, new uses are being found in machine shops, oil refineries, steel foundries and shipyards.

Multi-flame heating blowpipes are becoming increasingly popular in a new process for removing scale from billets, blooms, slabs, forgings and steel castings. When a high temperature flame quickly heats the scale it expands and breaks away from the cold base metal. Oxy-acetylene descaling has a number of important advantages over cleaning by pickling, sandblasting or chipping.

The same principle has been applied with remarkable success to the preparation of structural steel for painting. When an oxy-acetylene flame is quickly passed over the metal surface a short time before the paint is applied, the surface is heated so rapidly that all moisture on the surface and within the scale and rust layers is driven off, breaking the scale and rust bond, and leaving the surface (after immediate wire-brushing) in a warm, dry and clean state conducive to even and long-lasting adherence of the paint. This process has been used on all types of structural steel work, storage tanks, boat hulls, pressure vessels, dams and locks, and piling and other marine structures. Some steel purchasers are specifying flame cleaning.

The recent introduction of a unique oxy-acetylene bar-cutting machine fills a long-felt need. Heretofore heavy and complicated attachments have been used on straight-line cutting machines to obtain the desired blowpipe motion when cutting rounds, in which the blowpipe must move in a vertical arc, or when cutting squares with a swinging blowpipe. The new machine is simple in operation, the correct motion for cutting rounds or squares being transmitted to the blowpipe by an easily adjusted, self-contained spring power unit, the speed of which is hydraulically controlled. The equipment is portable and can be moved at a moment's notice, since it uses neither electric power nor a guide track. The machine has a normal cutting range of from 2 in. to 10 in., but can be increased to 8 to 15 in. by means of special linkage arms.

Electric Welding in Shipbuilding
(Unionmelt Process)

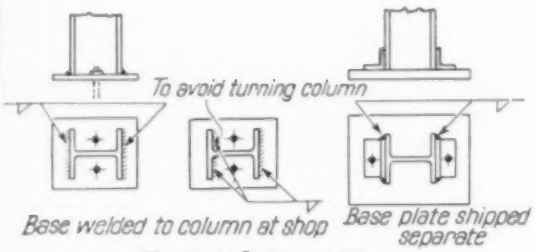
By T. M. Jackson
Chief Electrical and Welding Engineer
Sun Shipbuilding & Dry Dock Co.

ANNOUNCEMENT of the first all-welded tanker built at the Sun Shipbuilding & Dry Dock Co.'s yard for the Atlantic Refining Company in 1937, created great interest in shipbuilding circles. Today another all-welded ship is no cause for comment — it is commonplace. This company alone has completed eight all-welded tankers of large size and ten large cargo vessels which are more than 85% welded. Of some 43 other vessels now under construction or on order, 18 will be all-welded, and the balance about 85% welded. The first large all-welded cargo ship was recently launched by Ingalls Shipbuilding Corp., Pascagoula, Miss.

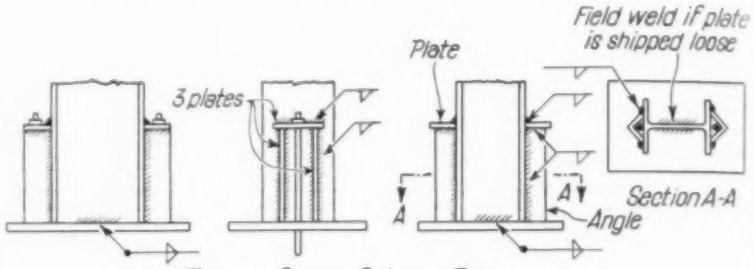
The time required to complete an all-welded hull at the Sun yard is now less than for a comparable riveted hull. Such speedy construction is possible by use of the "Unionmelt process", well enough known to require no description. The first large scale application of

Welded Connections for Tier Buildings

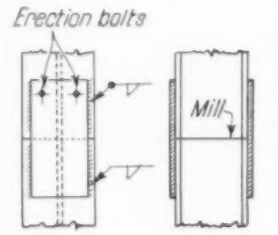
By permission, from American Institute of Steel Constuction's Tentative Standards, December, 1939



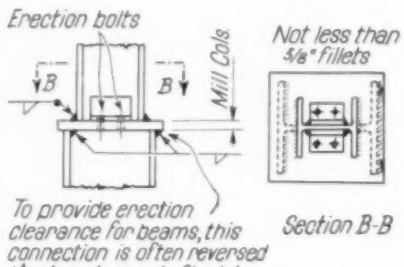
Typical Column Bases

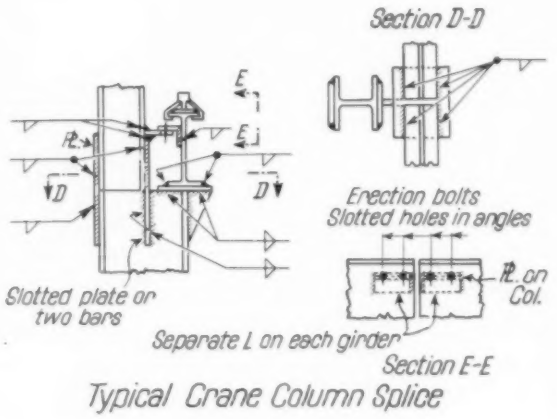


Typical Crane Column Bases

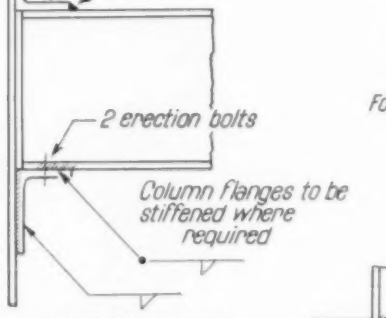


Typical Column Splices

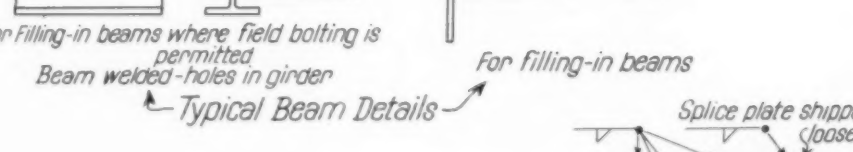

Erection bolts
B
B
Mill Cols
Not less than 5/16" fillets
Section B-B
To provide erection clearance for beams, this connection is often reversed (Angle on lower shaft, plate on upper shaft.)
Preferred splice (No holes in main material)



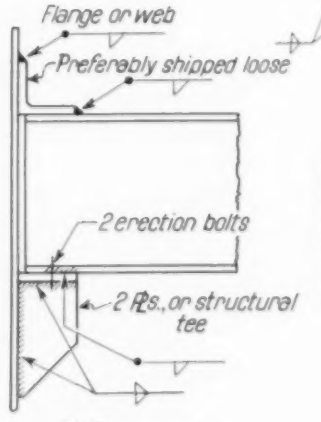
Typical Crane Column Splice



Unstiffened seat

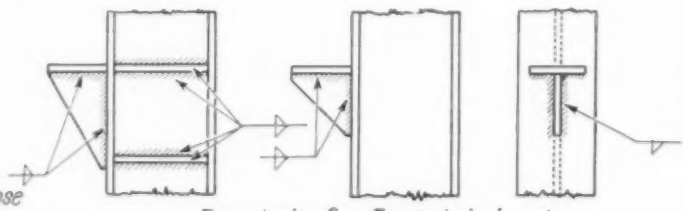


Typical Beam Details

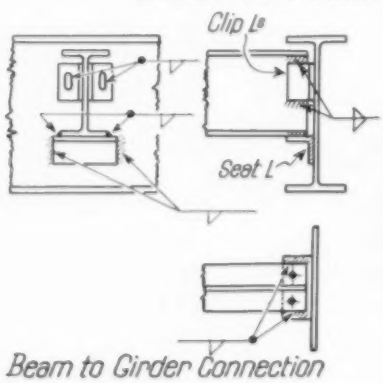


Stiffened seat

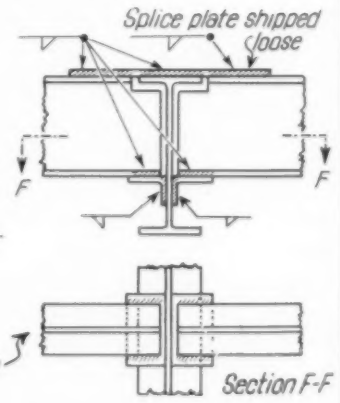
Beam to Column Connections



Brackets for Eccentric Loads



Beam to Girder Connection



Welds made with heavily coated electrodes only, and at temperatures above 25 °F. Fillet sizes ¼ or 5/16 in.; lighter fillets permissible on less than ½-in. plate. Welded structures must conform in design, fabrication and erection to American Welding Society's 'Code for Fusion Welding and Gas Cutting in Building Construction.' Rigid-end beams permissible only when specially designed for. Flexible beam connections shall permit rotation of top flange-ends an amount in inches equal to flexural unit stress in psi. at mid-span times span in feet divided by the constant 3,625,000.

this process to shipbuilding was made at the Sun yard in 1937. Our set-up is designed to make automatic fillet and butt welds on large shop sub-assemblies which are later erected on shipways and manually welded together. Sub-assemblies up to 40 by 40 ft. and weighing up to 35 tons are welded in the shop with the process.

This equipment, where the work is brought to the machine and positioned for flat welding, greatly increases the speed of fabricating these sub-assemblies. Fillet welds of the size required in merchant ship construction are made in one pass at speeds of 25 to 30 in. per min. Butt welds on plate up to 1¼ in. thick, about the heaviest required, are made in one pass completely through the section, the largest welds at speed of about 9 in. per min. Butts on ⅜-in. plate are made at a rate of 25 in. per min.; a light finishing pass is made on the underside of butt welds to insure complete penetration and good appearance. Currents up to 1700 amperes at 40 volts are employed.

The process, properly applied with competent supervision, produces sound, ductile welds having tensile strength and other physical properties at least equal to the parent plate. Welds so made are accepted by classification societies and government departments having supervision over merchant-ship construction.

The statements made above apply only to merchant ship construction. We understand that some application of the Unionmelt process has been made to vessels for the United States Navy in other yards.

Electric Arc Welding

By W. J. Chaffee
Welder Division
The Hobart Brothers Co.

IT IS IMPOSSIBLE to consider the status of electric arc welding at this time without due regard for the effects upon the industry of the conflict abroad. When we consider that arc welding received its first really big impetus in this country during the War of 1914-18 and that its growth and ramifications in the meantime have been truly remarkable, it seems only natural that it is assuming a considerable importance in our own defense activities as well as in more direct application to the present European war.

Manufacturers of arc welding equipment are finding their problems to be those of production rather than selling. Workmen have sensed this condition, and for many months welding schools throughout the country have been crowded with students preparing to meet the demand for operators. The National Youth Administration is placing more emphasis on welding as a trade. Operating through state agencies, temporary schools set up in the national defense training program include courses on arc welding.

Government requirements and purchases of arc welding equipment so far this year have been at least ten times as heavy as last year — with still heavier to come. Industries that have, or will receive, contracts to supply defense materials are steadily contributing to the growth of a mushrooming market; to say nothing of the demand by the normal commercial trade that finds it necessary to step up production to keep pace with the economic acceleration.

The aircraft industry seems to be paying more attention to the possibilities of arc welding in its speed-up program; special welding machines have been developed to simplify and improve the welding of light gage alloys peculiar to aircraft requirements. Whereas, arc welding was formerly considered only in the fabrication of jigs, it now looms as an important adjunct to actual plane construction.

In shipbuilding, where arc welding has long been a standard process for many operations, greater use is being made of all-welded construction. Hulls are being fabricated in sections by arc welding, these sections being joined together by arc welding on the ways.

Transportation on land, too, continues to make increasing use of arc welding in combination with resistance welding for the construction of steel coal cars, box cars, passenger cars — all feeling the trend toward streamlining. The same applies to automobiles, trucks, tractors and trailers.

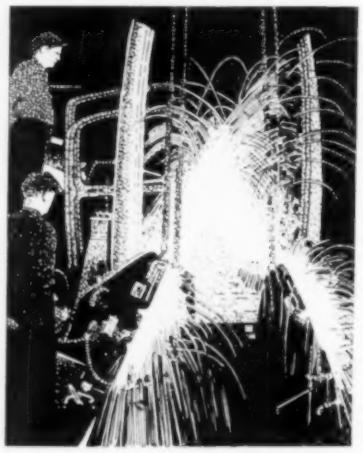
Experimental and development work, with

some actual production activity, continues in the field of housing. Many designs for part-steel and all-steel construction for medium and low priced dwellings have been projected, although most of them are still in the development stages.

Manufacturers of machine tools and all kinds of machinery are paying more attention to the possibilities of welded steel replacing iron castings.

Despite the obstacles to be overcome in selling abroad these days, from adverse exchange rates and shipping limitations, export sales to many countries have largely increased.

An interesting thought, right in line with the theme of the 1940 National Metal Exposition, "New Aids for Production", has been expressed by J. H. PATERSON, who is prominent in metallurgical, chemical and welding circles of Great Britain. Commenting recently on the future of welding, in an article in a British trade paper, DR. PATERSON says, in part:



"So much has been written and spoken on the subject of electric welding that anything one can say on the technical side of the subject must appear trite and commonplace.

"Out of all this welter of data and practical experiences, however, facts are gradually emerging which make it clear that the fusion welding of metals is bound to play a predominant part in the joining together of metal structures. So much so is this true, that metals or alloys of metal, which because of some inherent property cannot be properly joined together by fusion welding, will lose their economic importance altogether.

"The future of welding lies partly with the research engineer whose efforts to produce better and cheaper methods of production have already met with success, but mainly with the metallurgist who must provide industry with metals peculiarly suited to the welding process and at the same time satisfy the user with regard to their physical and mechanical properties.

"I believe that further modifications of all fusion welding processes are necessary in order to bring them to the highest pitch of perfection, but it is certain that once this perfection is attained, welding will take its place as the only acceptable method of joining metals."

Resistance Welding

By E. J. Del Vecchio
The Taylor-Winfield Corp.

THE PAST YEAR has witnessed several improvements in resistance welding operations and applications, and refinements in practically all types of equipment. The outstanding new development, however, is undoubtedly the introduction of the stored energy principle, so far being applied primarily to the spot welding of strong aluminum alloys, particularly as used in the aircraft industry.

The method, known as "Hi-Wave welding", consists essentially of charging a bank of condensors or capacitors and then discharging them through a transformer which sets up a secondary current which, in turn, heats the spot for welding. It has two principal advantages over conventional welding by alternating current, one of which is that the quality of the weld is increased; consistent welds are obtained which are free from cracks or other flaws; the size of the spot-weld bubble is readily controlled and its cast structure is fine granular. The other advantage lies in the reduction of the power demand; with the conventional resistance machine, instantaneous power demands of 400 and 500 kva. are quite common, but with the Hi-Wave method the demand is reduced to about 1/10 of this figure, with corresponding reductions in cost of electrical installations. Not only is the demand reduced to 10% of the former figure, but this demand is also taken from all three phases of a 3-phase line, and the power factor is relatively high.

Another important contributing advantage is reduced maintenance of the welding tips. In conventional machines, it is necessary to clean the welding points frequently, sometimes every ten or twelve spots, while with the new method and rigid machine construction preventing any skidding of electrodes while the current is on, runs of several hundred are made without fouling the tips.

All indications point to this new method of welding being widely accepted in the aircraft industry and no doubt it will replace thousands of rivets. Aluminum welding generally will be benefited. There are distinct advantages when used for welding stainless steel and other alloys.

Another related advancement is the "Vanco

method" of percussive butt welding. While percussive butt welding, itself, is not new, satisfactory commercial equipment has only been available lately. By this method, a capacitor bank is charged to a relatively high voltage, which voltage is then applied to two rods, tubes or other members to be butt welded, which pieces are separated from one another by about 1 in. air gap. As soon as this potential has been applied, one of the pieces is moved toward the other by an air cylinder. When it arrives at about $\frac{1}{16}$ in. from the stationary member, the voltage jumps the gap, discharging the condensers in a very short time, and the weld is completed by the time the two members have actually contacted one another.

Much heat is generated in this operation, but since it is generated so fast, it is localized so much that the welded pieces may be removed almost without sensible heat. The operation may be compared to a lightning discharge, only of course upon a much smaller scale, and the instantaneous application of power reaches a peak of about 35,000 kva. even for a small weld such as between two pieces of $\frac{3}{8}$-in. rod.

Percussive welding has so far been successfully applied to nearly all combinations of metal, including cast iron, malleable iron, cast steel, high speed steel, tungsten, copper, brass and aluminum. It is especially useful for such metals or combinations as cannot be satisfactorily welded in any other manner, such as copper to cast iron, tungsten to copper, and so on.

Resistance welding of the conventional sort continues to play a very large part in automobile construction. While no radically new methods of welding will probably be employed in 1941 cars, it continues to play an important role in holding the cost of cars stationary in spite of increasing costs in labor and materials. One notable example is in one of the 1941 cars, made with a frame which will be entirely resistance welded from stampings, almost completely eliminating the use of rivets.

The art of constructing railway passenger and freight cars by resistance welding continues to advance. While up to the present time probably no great reduction in cost to manufacture has come about by its use, it does appear that as the design of these cars and their construction become better and better adapted to resistance welding, costs will inevitably come down. Typical applications now are two — one being portable spot welders for assemblies in large jigs, and the other multi-point welders designed and built for specified car designs.

Resistance welding continues to be used in the fabrication of building materials such as "steel lumber" and small beams, all of which will probably lead up to the pre-fabrication of residential and industrial buildings. While there has not been a great amount of progress made so far, it appears that this is likely to become one of the next big industrial developments.

A rapid introduction of more alloy steels during the past few years has introduced new resistance welding problems but the industry has kept pace with these new alloys and welding technique has been developed for all, almost without exception.

Brazing and high temperature soldering by means of resistance generated heat continues in a large number of applications. This method is successfully fabricating non-ferrous switch and gear parts, and manufacturing small relay contacts in high production.

Oxy-Acetylene Welding

By J. H. Zimmerman
Development Manager, The Linde Air Products Co.

INCREASED ACTIVITY of the metal-fabrication industries during the past year has resulted in an increased use of all methods of welding. That the various applications of oxy-acetylene welding are fully sharing this expansion is evidenced by the steadily increasing sales of rod and supplies for gas welding. Generally speaking, the widening use of the oxy-acetylene method may be ascribed to *(a)* the wider employment of recommended techniques and procedure controls resulting in a higher quality of workmanship, *(b)* the introduction of new and improved equipment and welding supplies, and *(c)* a more universal recognition of the inherent advantages of the oxy-acetylene process for certain types of work.

Speed of Manual Arc Welding

In down position and 100% operation factor. Discount speeds according to efficiency of shop management up to 50% for piece work and 67% for day work

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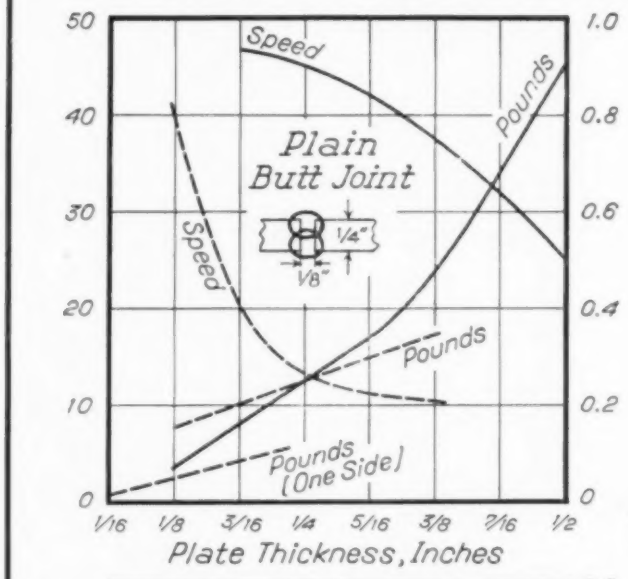
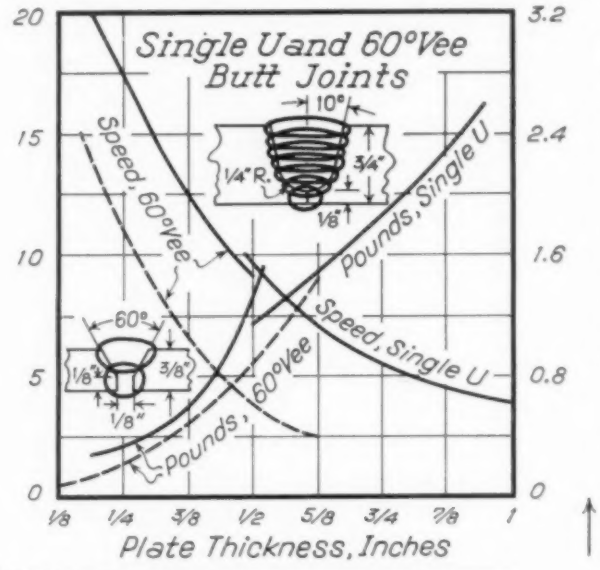
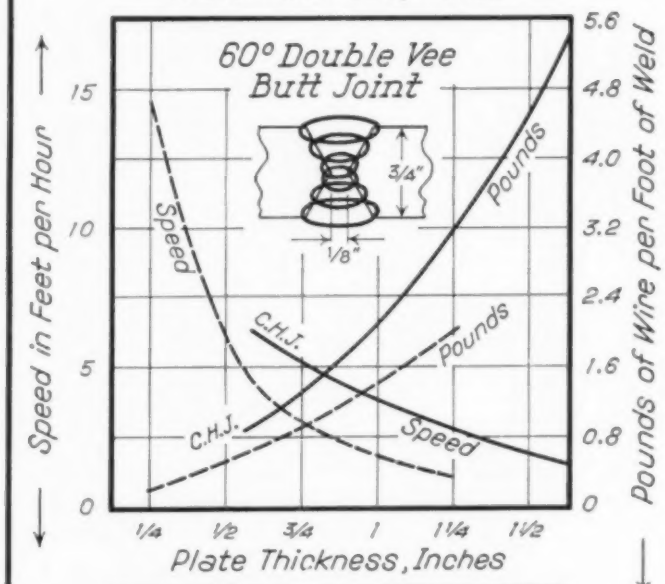
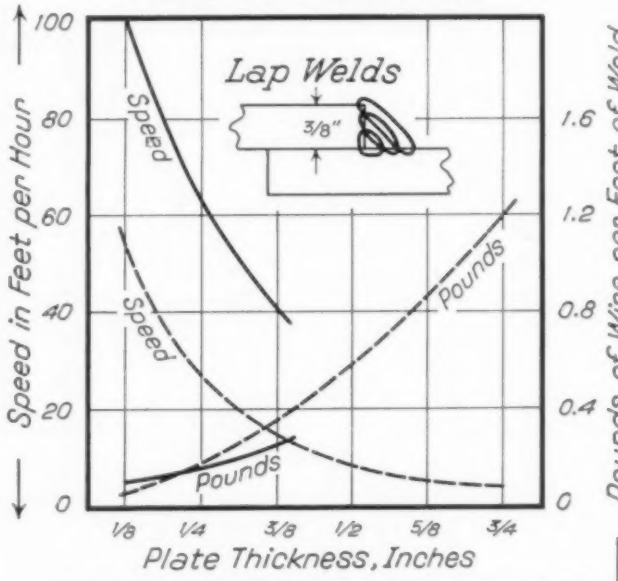
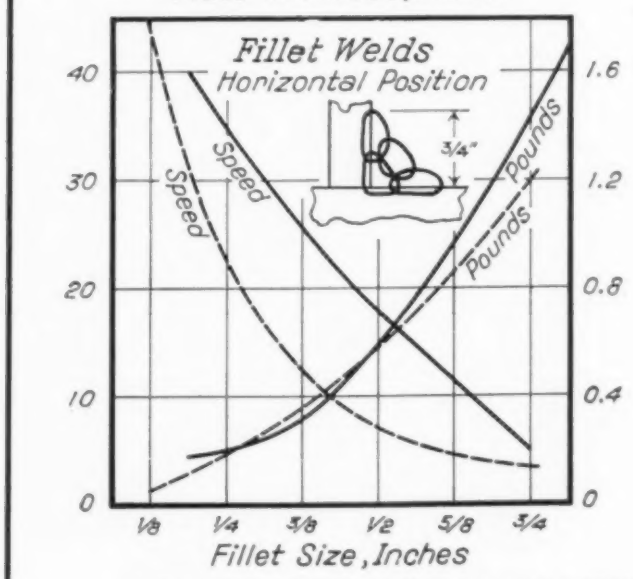
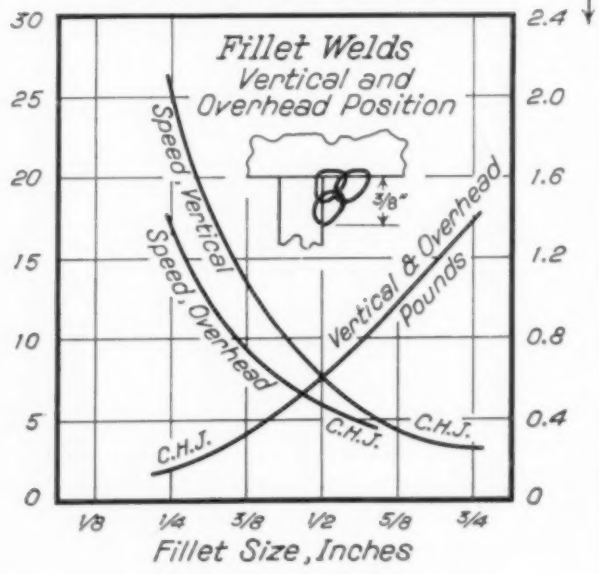












Data from "Procedure Handbook of Arc Welding", Lincoln Electric Co., except curves marked C.H.J. from "How to Weld 29 Metals" by Charles H. Jennings, Westinghouse Elec. & Mfg. Co.

Probably one of its most important advantages is its flexibility. Many plants are today faced with the necessity of quickly making extensive alterations to increase their productive capacity, and very often these must be made without shut-downs or loss of working time. The problem is sometimes further complicated by delays in the delivery of certain fittings, metal parts and other important items. An operator equipped with a supply of stock shapes, a welding blowpipe, and an oxy-acetylene cutting blowpipe, can very often make elaborate changes in equipment or building facilities by cutting away here, adding there, without interrupting the normal operations of the plant, and by fabricating — right on the job — many special parts or fittings.

This same element of flexibility of the oxy-acetylene process is of tremendous importance to industrial piping, particularly where it must be installed close to irregular contours of buildings. Its efficiency as a method of pipe fabrication has been increased considerably by the "multi-layer welding" technique for the heavier wall pipe which fulfills the prime requisite of quality welds procurable from a workman of average welding ability. The oxy-acetylene flame is also ideal for "wrinkle-bending", whereby pipe can be bent quickly to any desired angle.

Bronze welding continues to be an important and versatile application for fabrication on a production scale and for reclamation and building-up operations. Its efficiency and value in production have been greatly increased by the introduction of a liquid flux and flux dispenser. The dispenser provides a means for bubbling acetylene through the liquid flux so that the latter, in vapor form, is picked up and carried through the hose and blowpipe to the flame, where it produces the required fluxing effect upon the metals being joined. Waste due to excessive use of flux is impossible, and bronze welding applications by this method are considerably speeded.

In general, bronze welding offers the advantages of speed, economy and ability to do jobs which otherwise might be difficult or impossible, particularly in joining metals of high melting point, such as cast iron, steel, nickel and copper. A new bronze rod, developed especially for building-up bearing areas, has increased the use of the process for the rehabilitation of wearing surfaces on cast iron, steel and manganese bronze parts.

There is a noticeable trend to the use of the oxy-acetylene flame for the welding of thin gage material. In fact, it can be said that gas welding is the undisputed method for many such operations. In production welding, it is interesting to note the expanding use of multi-flame welding tips and mechanization of the blowpipe with respect to the work. Thus mechanized gas welding is proving an increasingly useful method for producing continuous strip metal, and for fabricating tubing, barrels and other ferrous and non-ferrous containers.

Atomic Hydrogen Arc Welding

By R. F. Wyer
Industrial Department
General Electric Co.

NEWEST of the fusion welding processes, atomic hydrogen arc welding is rapidly taking an important place as a repair tool as well as a fabrication process. It combines the advantages of easy manipulation and accurate control of penetration with the inexpensive heat characteristic of arc welding. It also has two particularly valuable features, the reducing nature of the atomic hydrogen in the zone of welding, and the extremely high rate of heat transfer or surface heating available with the atomic hydrogen flame. The rate of surface heating is easily controllable and can be almost double the highest rate obtainable with the oxy-acetylene welding torch. While this factor is not so important where large amounts of metal must be heated, as in melting down material for a heavy fillet or butt weld, it becomes extremely important for high speed welding of thin material, and where thermal distortion of the surrounding material must be minimized.

Technically, the range of application for atomic hydrogen welding is extremely broad. Although applications on such thin stock are rarely encountered, material 0.010 in. thick has been butt welded by this process. At the other end of the scale it has been used for $\frac{3}{8}$-in. fillets on forgings $\frac{3}{8}$ to $\frac{1}{2}$ in. thick. For economic reasons, however, the process is usually limited to those places where large amounts of metal do not have to be melted — the exceptions being where the desired physical properties of the deposited material cannot be obtained in other ways. A particularly attractive feature of the process is that practically any of the commonly used base materials can be welded; where necessary, filler material can be frequently obtained

from scraps of the base material, or even machined from the work-piece itself.

In the repair field its widest application is in surface welds, such as to build up worn surfaces on dies, molds and tools. Here the very high rates of surface heating are valuable in giving a quick weld with minimum distortion of the base material. The reducing envelope of atomic hydrogen gas prevents oxidation of the surface being built up, and helps produce the extremely sound, dense deposited metal which is most important in this class of work. In mold and die work, the process has made tremendous savings because of the speed and ease with which worn parts can be built up and errors in the tool room corrected. One large plastic molding plant, for example, recently reported 46 pieces welded in a five-day week, the average time per piece charged to welding being only 25 min. Yet the value of the molds thus reconditioned at negligible cost was close to $1600.

In the fabrication field, both automatic and manual atomic hydrogen welding is in use where high tensile strength, high ductility, and unusual soundness of deposited material is required. Several single arc automatic welding heads are fabricating steel and alloy tubing. Where thick material and high production speed require large amounts of heat, multiple heads are used, in which the seam is traversed by several arcs in tandem. Other automatic welding includes the fabrication of hollow steel balls, beverage barrels, and the welding of steel sheets to form long, continuous coils.

Characteristics of Multi-Pass Welds

By Charles H. Jennings
Welding Engineer
Westinghouse Research Laboratories

CONTINUED PROGRESS in welding has resulted in the fabrication of larger structures and an increased use of multi-pass welds. It is important, therefore, that everyone interested in welding become more familiar with the characteristics of such heavy welds.

Multi-pass welds are subject to the same defects as single-pass welds, such as lack of penetration, overlap, undercut, slag and oxide inclusions, gas inclusions, poor fusion, and shrinkage cracks. All seven types of defects may occur with the first pass, while only the last six may occur with the remaining.

Undercut and overlap are generally not serious when they occur in the intermediate passes because the subsequent passes, properly applied, correct them. Inclusions, once obtained, will not be removed by subsequent passes unless they are very close to the surface and melt out by the heat and fusion of the next pass. Lack of fusion in any pass will not be corrected by subsequent passes.

Gas inclusions and shrinkage cracks are sometimes caused by impurities and laminations in the parent metal. Heavy plates seem to contain more impurities than thin plates (which are frequently the product of continuous sheet mills); consequently the multi-pass welds may contain these flaws near the fusion line.

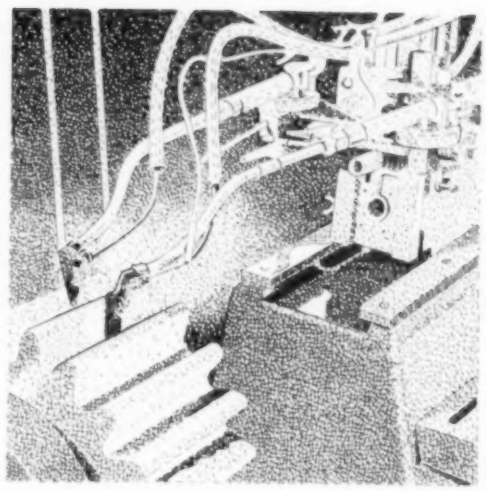
The increased puddling required on the final layers of a multi-pass weld (because of the wider area to be filled) results in the weld metal being molten for a longer period of time. This condition tends to reduce gas inclusions but may increase slag inclusions because of the larger volume of molten protective slag that must be controlled.

It is erroneous to believe that the diameter of gas inclusions can be controlled by the thickness of the passes — for instance, that a $\frac{1}{16}$-in. thick pass will not have any gas inclusion larger in diameter than $\frac{1}{16}$ in. Experience indicates that gas inclusions in one pass will progress upward through additional passes. Gas inclusions $\frac{5}{8}$ in. deep have been obtained in welds made with $\frac{1}{8}$-in. thick passes. It may be expected, therefore, that gas inclusions existing in multi-pass welds can be larger than in single-pass welds.

Single-pass welds always have a coarse, dendritic type of grain structure. In multi-pass welding on steel the heat produced when depositing one pass will tend to refine the structure of the pass immediately below and adjacent to it. The amount of grain refinement obtained depends upon the thickness of the passes, welding technique, plate size, temperature of the work — to mention some of the conditions. Excessively thick underpasses will only be partially refined; consequently in such cases the weld will contain areas of both fine and coarse grains. (The top or last layer deposited will, of course, always have a coarse-grained structure unless properly heat treated subsequent to welding.) The ideal weld is one where the grain structure of the intermediate passes has been completely refined.

The physical characteristics of a multi-

pass weld will vary somewhat with the method of welding. Within certain limits the tensile strength obtained in a weld made with a given electrode, welding current and joint design will increase with an increase in the number of passes. As the tensile strength increases, the ductility decreases. Also, the warmer the weld remains between subsequent passes, the greater the ductility will be. Increase in ductility in such cases is accompanied by a slight reduction in tensile strength.



The properties of deposited weld metal are often influenced by pick-up from the parent metal. In single-pass welds the pick-up may be very great. An extreme instance is welds made on low carbon steel with austenitic type 18-8 stainless steel electrodes, which will often be diluted with enough of the parent metal to become martensitic. In a multi-pass weld the joint width generally increases toward the top of the plate; consequently the percentage of pick-up decreases with subsequent layers. The result is a weld with chemical and physical properties that vary from the bottom to the top of the joint. This condition may or may not be important, depending upon the combination of steel and weld metal used and the service to which the welded joint is to be subjected.

Distortion in joints welded from only one side increases with the number of passes deposited. Controlling the number of passes on a multi-pass weld therefore has a great influence on the over-all distortion of a welded product.

Flame Hardening and Softening

By Raymond L. Rolf
Metallurgical Engineer
Lakeside Steel Improvement Co.

WHILE flame hardening has made vast progress since its introduction into the United States, it has not been until recently that methods and technique have been developed which will expand its application.

With the successful development of suitable equipment it is now possible to harden uniformly long lengths of shafts or rolls by the spinning method. Formerly this method was limited in length by the necessary size of the equipment and the distortion thrown into the large heated area.

Earlier attempts to harden long cylindrical objects were by the spiral progressive method, but this left soft areas between the passes. The new combination method permits complete coverage without intervening soft areas in end-to-end hardening of cylindrical sections. This involves a simultaneous spinning and traverse motion between hardening heads and work.

In principle the method consists of suspending the object, such as a roll or shaft, vertically in a ring of flames and rotating it while the burner traverses the object from bottom to top. This heats a narrow band of metal uniformly around the periphery of the work. The quench follows and is uniform with a minimum amount of splashing.

This process has the advantage of producing a shaft or roll with a dense surface while retaining the tough, resilient properties of the core. It achieves

(a) A uniform case over the entire length of the piece.

(b) Maximum hardness of the material used.

(c) Case depths of $\frac{3}{8}$-in. without melting.

(d) No cracking or checking.

(e) Lowest gas consumption per unit area on shafts of all flame hardening methods.

(f) A minimum amount of distortion.

Diameters ranging from $\frac{7}{8}$ in. to 12 in. have been so hardened, although there appears to be no limitation to the sizes which can be handled. Lengths are limited by the weight and stiffness ratio of the part.

Steels which can be successfully hardened by the process, in addition to the ordinary flame hardening materials, include several other analyses which have been giving trouble, such as S.A.E. 1070, 4150, 6140, and 3145.

Rolls for steel mill applications require a $\frac{3}{8}$-in. case with $\frac{3}{16}$ in. of maximum hardness. Paper mill rolls require no more than $\frac{3}{16}$ in. total case depths, while such items as piston rods,

plungers and shafts, require only a light case.

Flame hardening today is being done on a production basis on many important parts. In each instance the core is left with the original structure and the case has a gradual transition from the hardened surface to the unhardened central sections.

Diametrically opposed to the basic demands for the flame hardening processes are the needs which have led to the development of "flame softening". In the first process the objective is to increase the surface hardness whereas in the second the purpose is to soften material which has been hardened. Included are such operations as the localized annealing of carburized and hardened parts to permit drilling or other machining after the hardening operation. Another application is in connection with the flame cutting of air hardening steels. These, when flame cut in the usual manner, may leave unmachinable edges lacking in toughness. The fundamental principle of this process, when used in conjunction with the flame cutting, is to apply such preheat and after-heat as may be necessary to anneal the cut edge and leave it in a ductile and machinable state.

This process avoids chipping or grinding the thin hardened surface which is left on the kerf of air hardenable steels. While the same results may be duplicated by furnacing, this method is usually more cumbersome and less economical.

Developments in Metal Spraying

By W. C. Reid
Metallizing Engineering Co., Inc.

METAL SPRAYING (or metallizing) is now so extensively used in all branches of industry and by the U.S. Army, Navy, and other governmental services that explanation of the process and its applications seems no longer to be necessary.

During the past few years, there have been many improvements in design of equipment. New and useful applications of the process have been developed, and promotion of the process in general has become much more effective.

Equipment has been developed to a point where it has become a rugged production tool, rather than a delicate and temperamental mechanism. The original "guns" designed to use only oxygen and acetylene have given way to equipment for efficient operation on all of the commercially used gases, such as manufactured gas, propane, natural gas and hydrogen. Wire sizes have increased from 19 B & S gage to ⅛ in. diameter, and spraying speeds have gone up in proportion.

Aside from the obvious utility of rebuilding worn surfaces, the important applications are now on new equipment whereby surfaces of special corrosion or wear resistance are prepared. Stainless steel sprayed on steel pump pistons, for instance, not only protects the base metal from corrosion by brackish waters, but also from abrasive wear by mud and sludge carried in suspension.

Three new processes have been developed to protect irons and steels from scaling at elevated temperatures. In the first one a coating of aluminum is sprayed on the cleaned metal, over which a liquid seal is then sprayed and the article is heat treated. At this time the aluminum and iron inter-diffuse and form a complex skin consisting of several thin layers. Deepest is an iron-rich solid solution of iron and aluminum, next are eutectic mixtures of iron-aluminum compounds, outside of which is an aluminum-rich solution of aluminum and iron merging into a layer of substantially pure aluminum overlaid by aluminum oxide. Such a structure lends excellent protection against normal atmospheres up to 1750° F., as well as when sulphurous gases are encountered.

The other two processes (patented) do not use aluminum but another alloy, and no special heat treatment, and are designed for higher temperatures (2000° F. and higher). Articles so protected have been successfully used for pots, ladles and troughs handling molten aluminum, salt pots and carburizing and annealing boxes, furnace parts, and gas engine exhaust stacks.

Another patented process (called "Spramold") uses a metallic spray of hard steel over a master design, building it up to such thickness that it can be used as a completed mold, or if thinner set into a separate backing. Where suitable to the process, molds for rubber, plastics and condensation products can thus be made with great fidelity to the original and at a small fraction of the cost of a die sunk or engraved in steel.

Finally may be mentioned the application of the metallizing process for the spraying of copper, quickly and easily, to stop-off those portions which are to be soft after the article has been carburized.

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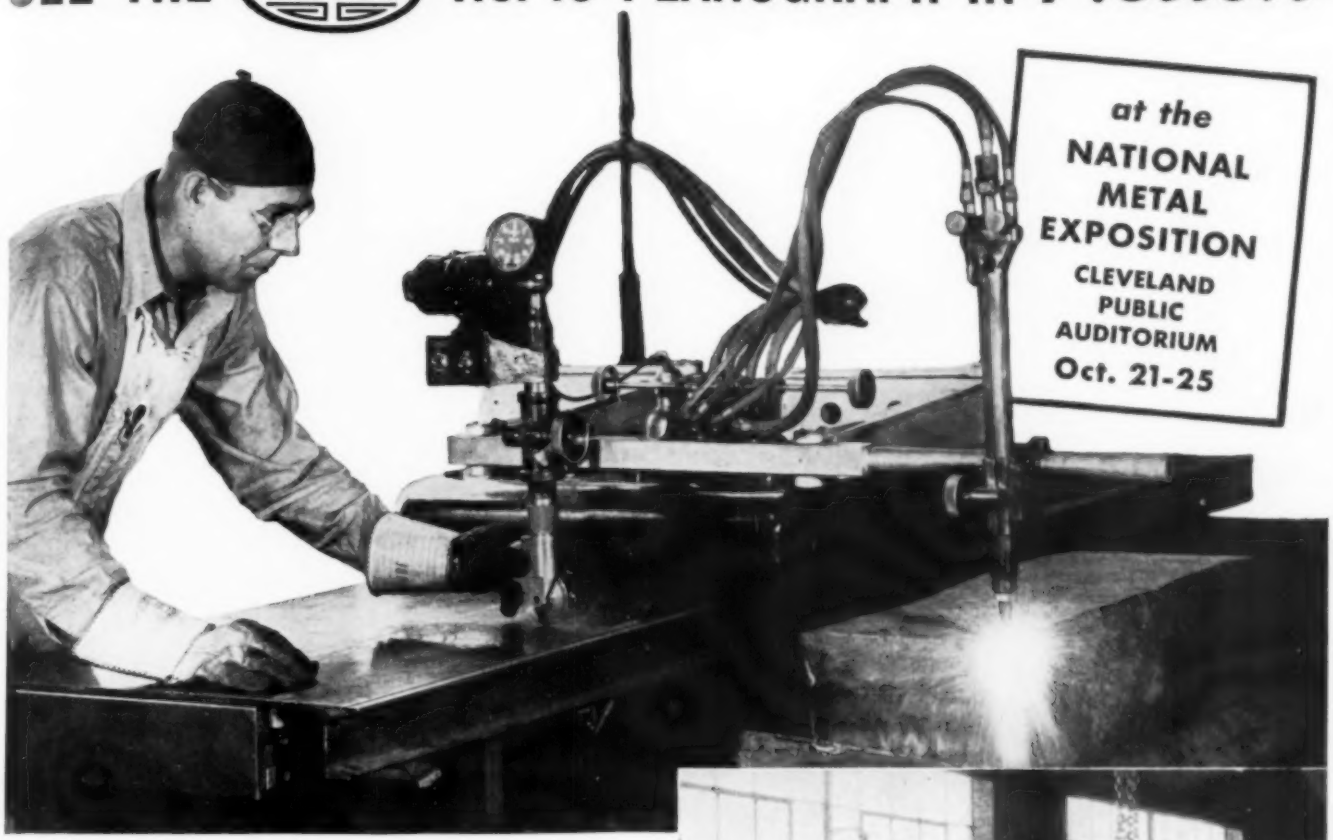
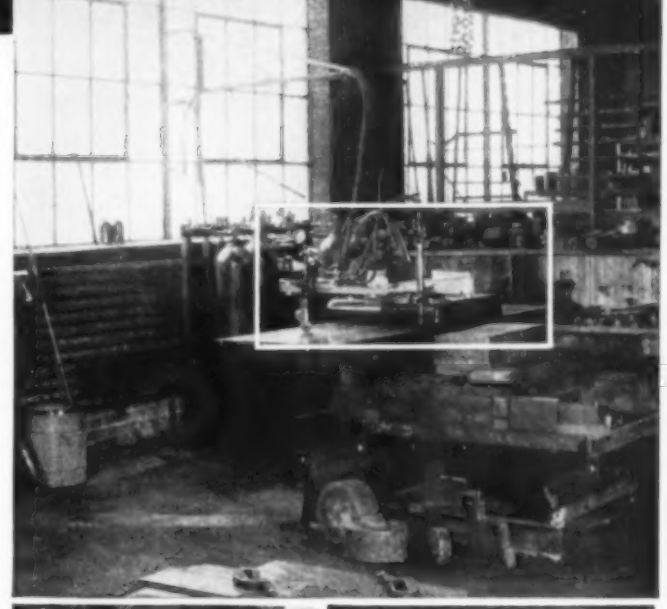
Alter Ego

SEE THE AIRCO No. 10 PLANOGRAPH IN *Action*



The No. 10 Planograph, one of an extensive line of gas cutting machines being widely used in America's National Defense program, will be the feature of Airco's display of the Metal Show. Already gaining wide acclaim because of its outstanding performance, this Planograph cuts straight lines, rectangles, circles, irregular shapes, etc. quickly and economically from ferrous metal of any thickness within the present practical limits of the cutting torch. A minimum of floor space is needed as the illustration to the right shows so well.

This is your opportunity to see the No. 10 Planograph in action . . . at Booth G-20, the Metal Show.



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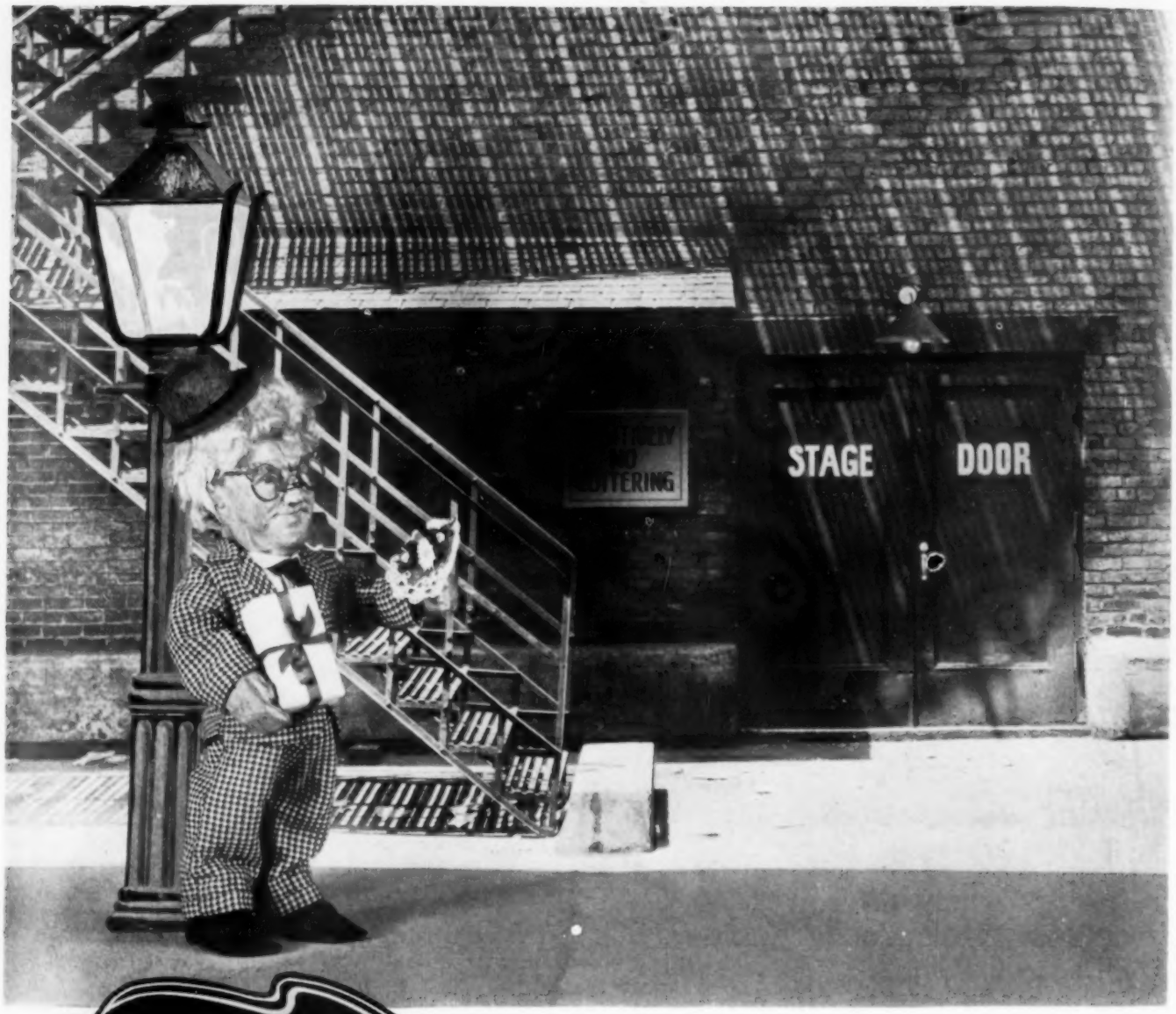

Whitey Sez:

"The fellow who complains that he is not getting enough is usually not giving enough... Even a welding rod to give the ultimate of service must be enriched with the best of materials."

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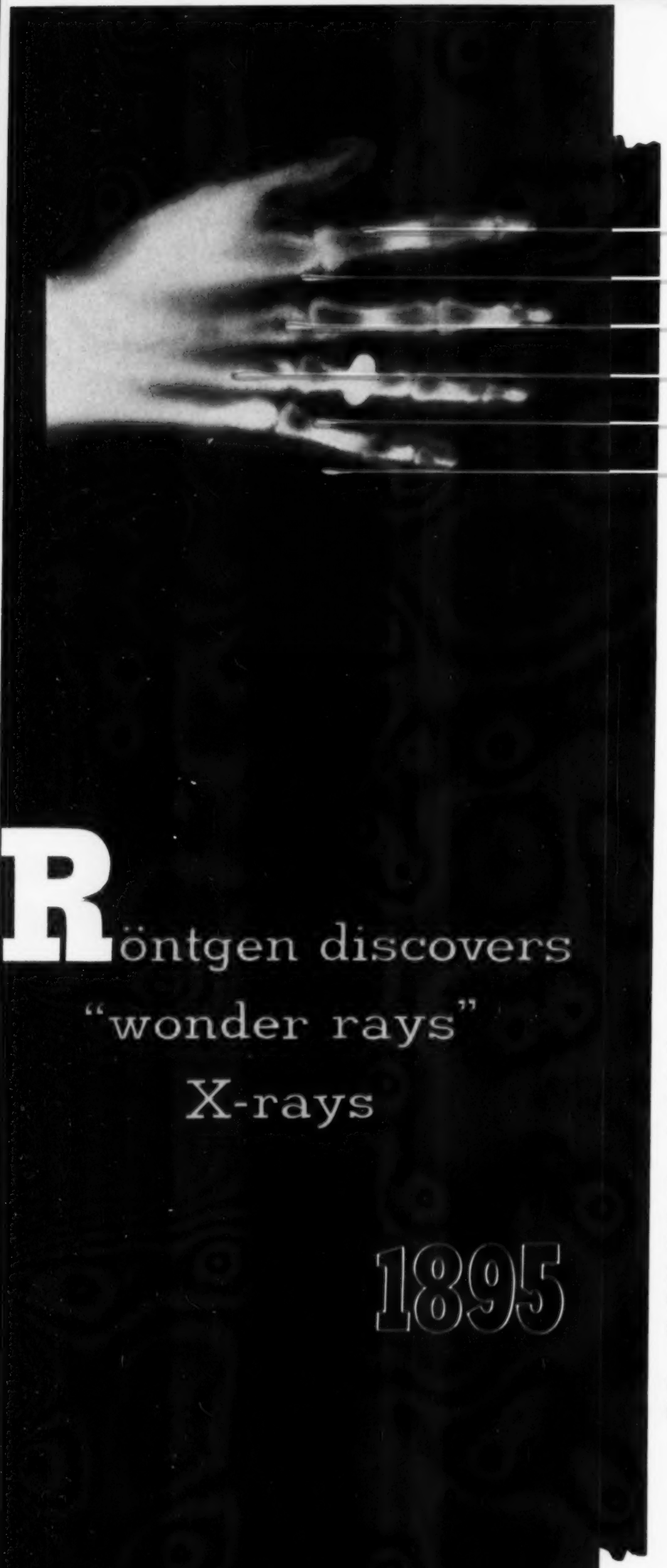
metal progress

forging



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Ordnance Research*
Removes a Bottleneck in Production

By Scott B. Ritchie
Lt. Col., Ordnance Department, U. S. Army
Director of Laboratory, Watertown Arsenal

PREPARATIONS for national defense are based upon the application in warfare of developments in the arts and sciences. Practically every advance in scientific and engineering knowledge has its place in our means of defense. Future wars will be decided by industrial preparedness and applied science. . . .

Greater and greater reliance is being placed upon machines. Unless they perform successfully, they may be worse than useless. We need the very highest quality obtainable, but we cannot lose sight of the fact that huge quantities of material are required to support a modern military effort. . . . There must be a suitable balance between the requirements on the one hand and the technical competence and capacity of industry on the other.

This suggests the importance of uniform standards and uniformity of metal products. There are some 7300 principal items of equipment and supply which must be procured for use of our troops, while the number of components for those complete articles totals hundreds of thousands. Many of the items are not in commercial production in our country. Consequently the exact production methods peculiar to these items are not generally known to industry. Yet the War Department must in a major emergency depend upon private industry for more than 90% of its requirements. . . .

Our designs must of course give us material at least the equal of that of other countries; but they must be based on the use of commercial materials and capable of being produced by commercial processes and methods. . . . The types adopted as standard must be of such character that they will permit mass production in sufficient quantities to meet requirements. . . .

The interchange of technical data and experience between civilian agencies and the War Department is especially valuable to national defense. Without this cooperation many of our advances in the art of munitions production would not have been possible. This is especially true with respect to the Ordnance Department.

Our system of industrial preparedness focuses attention upon the paramount importance of two fundamental factors in our industrial organization which have a direct application to the adequacy of munitions — first, *research and development* to insure the most effective material made possible under the existing state of the arts and sciences, and second, *production engineering* to insure that the items can be procured of satisfactory quality in mass production in the most efficient and economical manner. . . .

In these activities the arsenals play a major role. They are highly important in our scheme of national defense, not so much as production centers, but rather as experimental laboratories to keep alive the art of ordnance manufacture, to set standards, to determine costs, to uncover production difficulties, and to train inspectors.

The Chief of Ordnance regards research and development as responsibilities of the first magnitude. . . . In some countries abroad practically every university and every research organization is working intensively on military projects in one form or another. That is the situation with which we must compete. The Ordnance Department of course must be alert continuously as to engineering and scientific developments at home and abroad which, even though not primarily of a military character, may be used in producing more efficient fighting machines. . . .

Although funds available for research have been limited, accomplishments have more than justified the expenditures made. Typical of the developments since the World War in the metallurgical group alone, some of which have been of a high type of utilitarian service to the nation at large, may be listed: The centrifugal casting and cold working methods applied in gun manufacture, removable liners for artillery, introduction of new alloy gun steels, application of welding in the con-

*Editor's Note — This article is abridged from a talk before The Franklin Institute about a year ago (published in full in *Army Ordnance*, Sept.-Oct. 1939). Its importance warrants its reprinting here, and it gives another slant on the situation discussed in the first "Critical Point" in last month's Metal Progress. At the time this talk was given, Major Ritchie was Chief of the Allocations Division in the office of the Assistant Secretary of War.

struction of mobile gun carriages, improvements in light armor plate and armor piercing bullets, and developments in instruments and technique for examination of metals.

Ancillary to the developments just mentioned have been the improvements in testing methods, notably impact and X-ray. Both have had a beneficial influence in the production of better Ordnance metals. Deep therapy, to test for the existence of internal flaws, affords a process control for the foundry and the fabricating shop, especially in welding to develop proper welding technique in which such elements enter as skill of the welder, composition and thickness of plate, and type of welding rod. Similarly, diffraction X-ray equipment implements research into internal stresses, identification of crystalline structure, and other fundamental factors influencing the quality of metals.

The foregoing activities are mentioned merely to illustrate the type of metallurgical research with which the Department must deal. There are many basic problems waiting to be solved. . . .

The Ordnance Department, within the limitations of available funds, also conducts investigations to improve methods of manufacture. A typical case may be of interest:

As a result of the survey of industry incident to procurement planning it was found that the existing presses and draw benches suitable for production of the larger one-piece bomb cases (the only standard method of manufacture prior to the present fiscal year) was very limited and wholly inadequate to meet emergency requirements. The thickness of the metal in the nose section of this design of one-piece demolition bomb case limits the methods of manufacture to cupping a plate or piercing a billet and drawing. This process requires heavy presses and draw benches and considerable machining of the case is necessary to obtain finished dimensions. In war-time, therefore, this would also throw an extra burden on the machine tool industry, already limited in capacity.

It has been found that swaging or spinning a seamless tube to the required exterior shape and dimensions of a bomb case does not give the usual thickness in the nose section. However, a bomb case of equal or superior strength can be obtained by this method if the tubing be made from steel of higher physical properties. This development led to the manufacture in industry last year of large-diameter seamless tubing having a minimum tensile strength of 95,000 psi., which has been followed recently by the spinning on a commercial basis of large-diameter tubing having a minimum tensile strength of 105,000 psi.

Paralleling this has been the development in the manufacture of large bomb cases from formed and welded plate. This is now a standard process for manufacture. Further improvement in the physical properties of the steel in large-diameter seamless tubing and welded plate offers the possibility of obtaining bomb cases of superior qualities.

This improvement in bomb manufacture is typical of others continually in demand and is somewhat analogous to the production engineering in the manufacture of artillery shell described in a recent issue of *Army Ordnance* by Colonel CAMPBELL of Frankford Arsenal. ("Artillery Ammunition Production", by Lt. Col. LEVIN H. CAMPBELL, Jr., *Army Ordnance*, March-April, 1939.) In such work the Ordnance Department of course must take the initiative, but when our problems are properly presented industry fully cooperates in their solution. The result is mutually helpful and in the interest of industrial preparedness. . . .

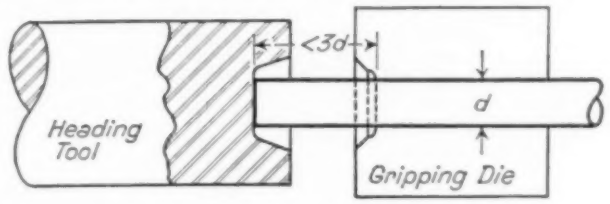
Gun erosion, optimum shell fragmentation, machinability, cartridge brass, improved armor plate and armor piercing projectiles, better gun steels, and improved welding, testing, and heat treating methods, ferrous and non-ferrous, are some of the fertile fields for physical and metallurgical research. There are many others. We need also much basic fundamental data both in the physical chemistry of steel making and in the field of physical metallurgy. Most of these problems are also industrial, but in certain cases we have specific fundamental problems, as in the determination of gun erosion and the mechanism of rupture of armor plate and projectiles. The closer we correlate our research and development work with industry, the surer are we to obtain satisfactory metals and shorten that vital transition period from M-day until industry is in mass production of essential items for the armed forces.

In conclusion, let me repeat that the Ordnance Department realizes the great importance of research and development to our national security. It attempts to capitalize not only on research provided by industry but also to utilize that provided through technical societies, college and university groups, other research organizations, and individuals with special technical knowledge. The increased complexity of military equipment, the huge quantities required, and the vital necessity for speed in production serve to emphasize the need for close correlation and application to ordnance of all data available. The ingenuity of the designer and the production manager also will be taxed to the utmost. Therefore, added emphasis must be placed upon projects leading to improved and simplified fabrication methods. This is one of the most promising ways in which to increase the war-time production rate. We must lean heavily upon the skill and facilities of private industry for research and for production engineering.

Rules Governing Forging Machine Dies

(Adapted from E. R. Frost; Courtesy National Machinery Co.)

Rule I — The limiting length of unsupported stock that can be gathered or upset in one blow without injurious buckling is three diameters.

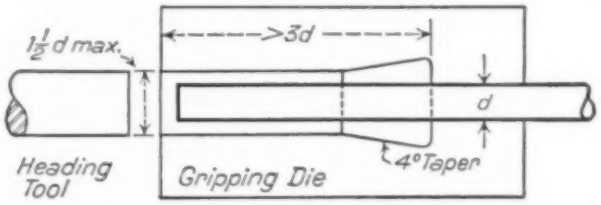


Note. (*a*): A safer maximum length is $2\frac{1}{2}d$; little attention need be paid to squareness of end if $l=2d$. If $l>3d$, buckling will occur near the middle of the unsupported length. These principles hold irrespective of whether the stock overhangs the face of the gripping dies, or whether any portion is gathered in either gripping dies, heading tool or both.

Rule II — Lengths of stock more than $3d$ can be gathered or upset in one blow provided the upset is contained in either the gripping die or a straight or slightly tapered hole in the heading tool, and the diameter of the upset made in that blow is not more than $1\frac{1}{2}d$.

Note (*a*): Multiple buckling will be checked by contact with sides of the die, and friction therewith will cause a fin to form around end of upset. Such long upsets cannot be made half in one die and half in the other, for central buckle will receive no side support.

Note (*b*): A safer maximum is $1.3d$, and if Rule I is also applied, the upset will be free from end fins.



Note (*c*): For very long upsets, it is helpful to have the end of the bar at a lower temperature, and to have a minimum diameter upset for the outer half of the die, the inner half tapering 4° to wider diameter at the base.

Note (*d*): In upsetting tubing, wall thickness cannot be increased externally more than 25% at one blow; internal upsets are almost unlimited because arch effect prevents internal buckling.

Rule III — For upsets requiring more than $3d$ in length of stock, and in which the upset is $1\frac{1}{2}d$, the amount of unsupported stock beyond the face of the die must not exceed $1d$ (operation 1, at right).

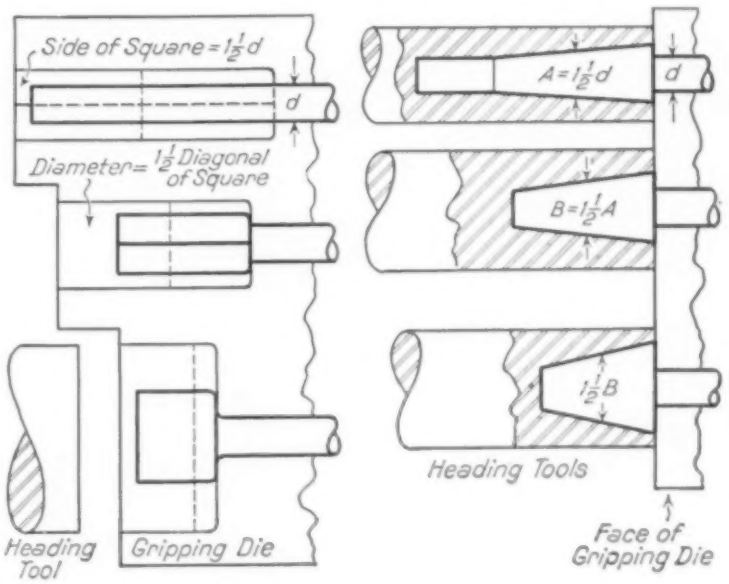
Note (*a*): Unsupported stock can amount to $1\frac{1}{2}d$ if diameter of upset is reduced to $1\frac{1}{4}d$.

Rule IV — Large amounts of stock can be gathered by multiple application of Rule II and III, and by using square or tapered impressions.

Note (*a*): In making the wide flange in sketch at left, below, the first and second impressions are within the $1\frac{1}{2}d$ limit, but the third, being a short upset under Rule I, is unlimited in diameter.

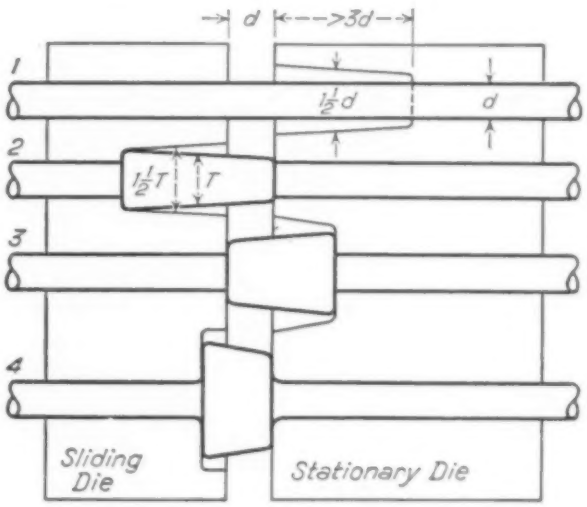
Note (*b*): The side of the square may be $1\frac{1}{2}d$ of the original bar, and the diameter of the next round may be $1\frac{1}{2}$ times the diagonal of the square.

Note (*c*): Tapered holes are proportioned as to their diameters at midlength of unsupported stock.



Rule V — Sliding dies, for upsetting stock at some distance from the end of a bar, are governed by all the above rules.

Note (*a*): Friction along the sides of the sliding die will favor upsetting near its front end, so multiple impressions should be alternately in front and rear half, or alternately in sliding die and gripping die, as shown in sketch below.



Quality Forgings

By E. O. Dixon
Chief Metallurgist, Ladish Drop Forge Co.

PERHAPS the most important development in the drop forging field during the past year may be described by the well-worn phrase of the military communiques — "consolidation of gains". Forged metal — traditionally the source of maximum engineering qualifications with respect to uniformity and strength combined with reliable toughness — has had bestowed upon it new responsibilities through its use for the more important aircraft applications. The important groundwork for this modern role has been laid in a few shops during the last few years. Now, with great increases in production schedules, has come the problem of putting on a volume basis the lessons learned.

It has been necessary to meet the rigid requirements for accurate control of grain flow with less dependence on the individual skill of the workman. New standards of mechanical excellence, of thinness and height of ribs, of surface, of freedom from decarburization, and of machinability are involved.

Throughout all this the principle must be kept in mind that design must be based on the *minimum* values of physical properties rather than averages, and that consequently below-par forgings must be avoided at all costs.

Worthy of special comment may be the refinements in heat treatment looking toward better machinability in forgings treated to minimum ultimate strengths of from 160,000 to 200,000 psi. Aircraft forgings are in most cases finish machined in the final heat treated condition. The important problem thus presented, with dimensional and surface requirements as they are, in many cases falls to the forge shop to solve.

Aside from aircraft developments, the forging field has advanced in the direction of slight reductions in draft requirements in special cases, and in improvements in heating to reduce amount of scale and decarburization.

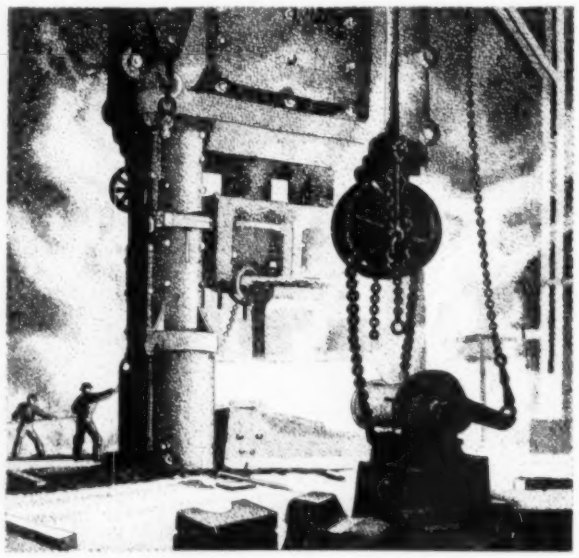
Large Press Forgings

By Adolph O. Schaefer
Engineer of Tests, The Midvale Co.

IN PREVIOUS YEARS, JOHN L. COX, chief engineer of The Midvale Co., has explained that manufacturers of large press forgings were marking time and attempting to maintain their skilled organizations. Manufacture of seamless boiler drums and reaction chambers, numerous types of shafting with a wide range of properties, and other kinds of heavy forgings, were extending the field of usefulness of this particular product of the steel industry. Certainly the knowledge and skill gained by this development work will be of value in the days ahead of us.

Forging technique in converting massive ingots into many of the various forms demanded by modern engineering has been described many times. It is worthy of emphasis here that accurate control starts in the steel melting furnace; correct ingot practice to insure a mass of sound steel, reasonably free from excessively segregated regions, is the first essential in the manufacture of large forgings.

Thirty years ago, prior to the last War, nickel was the principal strengthening alloy used in large masses of metal. In the intervening years we have learned much about the functions of other alloying elements, and something about how to use them. The amounts of the various alloying elements introduced into really large forgings are frequently prescribed not only to produce requisite properties of strength and ductility, but also to obtain special qualities such as hardness, creep strength, fatigue, impact, and resistance to some corrosive or penetrating medium.



Heating and heat treatment during all stages of manufacture are of utmost importance. In the present situation, in which the producing facilities of the nation are strained to the utmost, it is worthy of note that the heat treatment of large steel forgings cannot be hurried. Increased production can be obtained only from increased facilities. The time cycle

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for each operation is fixed largely by the mass of metal involved and its composition.

However, if increased facilities are to be made available for the manufacture of large steel forgings (which itself cannot be done in a few weeks) the problem is not entirely one of installing gigantic presses, heating furnaces and handling equipment. The responsibility placed on the men handling such work is great in proportion to the size of the forgings involved. The possible loss from error or oversight on the individual piece is exceedingly serious. Those men who have carried on the manufacture of this product during the last 20 years of depression and development may now be able to make a valuable contribution to the common welfare.

Armor

By William I. McInerney
Pittsburgh Crucible Steel Co.
Sometime Superintendent, Armor Treating Shop
U. S. Naval Ordnance Plant

THE TREND of world affairs in the past year has so revolutionized our thinking that we are now in a position diametrically opposite to public opinion a few years ago. The pendulum that once swung so far toward peace and disarmament is now gone further in the opposite direction. Where once we scrapped 35,000-ton ships that were building and never launched, we are now frantic to obtain even larger ships!

Obviously the heads of our various government agencies, whose business it is to protect the nation, must have at their direction equipment which is better than any enemy's, if they are to succeed in their responsibility. Considering the three essentials of equipment in any engagement, we must have armor, guns and projectiles. We will consider briefly the first of these items.

Battleship Armor — We have upped the displacement of our first-line ships to 45,000 tons, increasing the thickness of the armor and also the area protected, especially that which was found vulnerable from above, whether from high angle fire from an enemy's ship, or from the various types of bombs or other attack by airplane. Added protection in all cases is at the cost of additional weight, which means more horse-power is needed to get speed and ease of handling.

Of course it must be appreciated that a gun deck of sufficient size is necessary, especially in salvo firing, and this must also be of very substantial construction. This penalty of dead weight challenges our ability to provide more ballistic value per ton of armor and while progress can be reported there is still much to be desired. We need some further tremendous improvement, like our present day alloy steel armor as compared with the puddled iron armor of 75 years ago.

We are returning to the basic type of design exemplified by the Monitor of Civil War days, which takes advantage of the water for protection of magazines and vital machinery. (In the battle of Jutland several British ships were put out of action by shells that seemed to fall out of the sky, penetrating below decks by way of ventilating equipment or funnels.) We will some day perhaps exhaust everything at the stern or underwater, so that any part above the water line is equally protected, as far as possible, from attack at any angle.

Tanks — The total tonnage of armor for projected tanks is approaching that for battleships, and in development promises to parallel the experiences of the old line armor makers. At the present the general designs for tanks call for flat rectangular armor plates, but no doubt the influence of streamlining and ballistic value will become apparent along with new ideas regarding analysis and treatment.

Comparing tank armor with battleship armor, we find, for instance, the belt armor on the first line ship to be 13½ in. in thickness, while the armor on the new tanks will approximate 1 in. in thickness. Here again mobility and dead weight are factors in "who comes out on top" in the contest between armored mobile fortresses and armor-piercing projectiles.

Airplanes — At the present moment a limit as to weight of armor an aircraft can carry has been fixed, which means both thickness permitted and area covered. So we have a challenge to try many materials other than steel or the metallic alloys. Several combinations are being perfected and patents have been issued on different combinations of steel, rubber, glass and other materials that are all more or less related to the basic reason for any armor, and its adaptation to the purpose of protection. We also expect that certain theoretical analyses likely to give high ballistic values, but impossible to roll into plates, can now be cast centrifugally into cylinders of whatever thickness desired, and then formed and treated for the lighter gage plates.

Toolsteels for Hot Working Iron and Steel

By H. E. Replogle, Crucible Steel Co. of America

Requirements for All Hot Work Tools:

1. Of sufficient toughness to resist working stresses.
2. Of such composition and in such heat treated condition as to resist softening when in service.
3. To have adequate wear resisting properties to assure normal, economical life.
4. Of such composition and heat treated condition as to wholly or partially resist the tendency towards heat or fire checking.

Influence of Design:

1. Wedge designs, sharp corners and thin sections promote chances of breakage and require inherently tougher compositions, usually secured through lower total alloy content steels.
2. Designs including raised sections partially or wholly buried in hot metal require types of higher red hardness and may not require as high toughness characteristics as other wedge designs.

Importance of Mechanical Set-Up:

1. All forging dies should be properly lined up.
2. Machines should be true to assure uniform application of pressure or impact.
3. Dies should be so adjusted in hand fed and automatic forging machines as to prevent excessive pressure being developed on the faces of the dies, thus decreasing probability of fatigue failures.
4. Dies should not be mounted in worn or warped shoes or holders.

Importance of Adequate Preheating:

1. Well warmed dies and tools are less susceptible to cracking.
2. Minimum temperatures secured through use of buried unit heaters in certain types of drop forging dies prolong service life and retard heat checking.

Importance of Cooling:

1. Methods of cooling—Air, Oil, Water. Retards localized heating which may exert a tempering and softening action.
   - a—Air cooling least drastic—applicable to all types of tools. Also serves to blow away scale which, if present, will cause undue wear of dies.
   - b—Oil cooling—somewhat more severe and rapid but rarely detrimental to any tool or die.
   - c—Water cooling—most effective, but very drastic and often dangerous. When large dies attain high temperatures, water cooling tends to cause heat checking. Punches and small dies are often successfully cooled with an ample flow of water.

Influence of Die and Tool Lubrication:

1. Heavy graphite bearing greases serve as lubricants and prevent sticking. Usually assures better wear.

Quenching:

Among the data given below are recommendations as to the quenching medium; oil, air and "oil & air". The words "oil & air" signify an interrupted or timed quench. With this method, a tool or die is quenched in oil to a temperature of about 1000° F., or where all color disappears. When this state is reached, the tool or die is removed and allowed to cool naturally in still air until cool enough to be handled in the bare hands. It should then be drawn as directed.

Recommended Compositions, Heat Treatments and Hardnesses

Analyses, %								Heat Treatment (°F.)				
C	Mn	Si	Ni	Cr	V	W	Mo	Pre-Heat	High Heat	Quench	Draw	Brinell Hardness
Insert Dies in Upsetters												
0.55	0.25	....	....	1.25	0.18	2.75	....	1400	1750	Oil	1200	400 to 450
0.30	0.40	1.00	....	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450
0.30	0.30	....	....	3.25	0.25	9.00	....	1450	2150	Oil & Air	1200	400 to 450
0.25	0.20	....	....	4.00	0.50	15.00	....	1550	2350	Oil & Air	1200	400 to 450
Presses, Preloaded Dies												
0.40	0.30	....	....	1.75	0.18	11.00	....	155[illegible]	2150	Air	1100	539 to 578
0.45	0.30	....	....	2.75	0.40	15.00	....	1550	2200	Air	1150	539 to 578
Gripper Dies for Hand Fed Machines												
0.55	0.25	....	....	1.25	0.18	2.75	....	1200	1750	Oil	1100	450 to 500
0.55	0.30	0.40	....	4.00	1.00	....	0.50	1200	1650	Air	800	450 to 500
0.30	0.30	....	....	3.25	0.25	9.00	....	1200	2150	Air	1150	450 to 500
Gripper Dies for Automatic Machines												
0.30	0.40	1.00	....	5.00	....	1.30	1.45	1400	1850	Air	1050	444 to 526
0.55	0.35	....	....	4.00	1.00	....	0.50	1200	1625	Air	1000	444 to 526
Header Dies for Hand Fed Machines												
0.55	0.25	....	....	1.25	0.18	2.75	....	1200	1800	Oil	1225	430 to 461
0.30	0.30	....	....	3.25	0.25	9.00	....	1450	2150	Air	1175	430 to 461
0.30	0.40	1.00	....	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450
Header Dies for Automatic Machines												
0.55	0.25	....	....	1.25	0.18	2.75	....	1200	1800	Oil	1250	388 to 429
0.30	0.40	1.00	....	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450
Forging Punches												
0.30	0.30	....	....	3.25	0.25	9.00	....	1500	2250	Oil & Air	1175	425 to 450
0.30	0.40	1.00	....	5.00	....	1.30	1.45	1400	1850	Air	1100	400 to 450

The above data do not represent all of the types being used for the various applications listed, nor do they represent the only heat treatments or hardness values for these types. Neither do the above listings include flat, cut and swaging dies used in beam, steam or air hammers. However, the types and treatments listed represent the broadest general selections being used commercially today in the services noted.

Improved Die Steels

By H. E. Replogle
Toolsteel Division, Crucible Steel Co. of America

DURING the past year there has been a considerable study made of the hot work type of steels available for forging dies. Thorough testing in the forge shop has indicated the desirability of the group roughly identified as the "5% chromium hot work steels" and mentioned in "Critical Points" in August METAL PROGRESS.

A steel in the low carbon range, alloyed with tungsten and molybdenum, shows particular promise for insert dies for drop forging work as well as for gripper dies and piercers on upsetter forging machines. A typical analysis is 0.30% C, 1.00% Si, 5.00% Cr, 1.30% W and 1.45% Mo. Capable of withstanding abuse such as water cooling, difficult designs, and abrasive scales, this type has made uniformly high production runs at high hardnesses on drop forging work, as well as improved resistance to heat checking. A thorough study of this type is recommended for the applications listed above.

A more spectacular but more limited field has opened up in the use of the high carbon, 5% chromium type for hot work applications. The type is generally considered for punch and die applications on cold work only. A typical analysis is 0.95% C, 0.35% Si, 5.25% Cr, 0.50% V and 1.15% Mo. To the considerable surprise of many experienced forging and toolsteel men, this type, formerly considered only for cold work punches and dies, has made unusually long runs as both forging press or hot coining press dies and drop forging dies when tempered to a hardness of 450 to 477 Brinell. Its possible applications are as yet unknown; however, on comparatively simple designs, when used as an insert, it is usually free from heat checking, and has high resistance to abrasive wear from scale.

Present indications are that where this group is applicable it may consistently outperform many of the more expensive tungsten die steels. However, the prospective user should be warned that loose machines, poor fits between insert and holder, and careless set-up will almost certainly prevent success; only simple designs should be tried where there is a minimum of side or splitting stresses. When properly applied, heat treated and set up, this group has shown every indication that it must be considered as one of the valuable hot work steels available to us.

Aircraft Engine Forgings

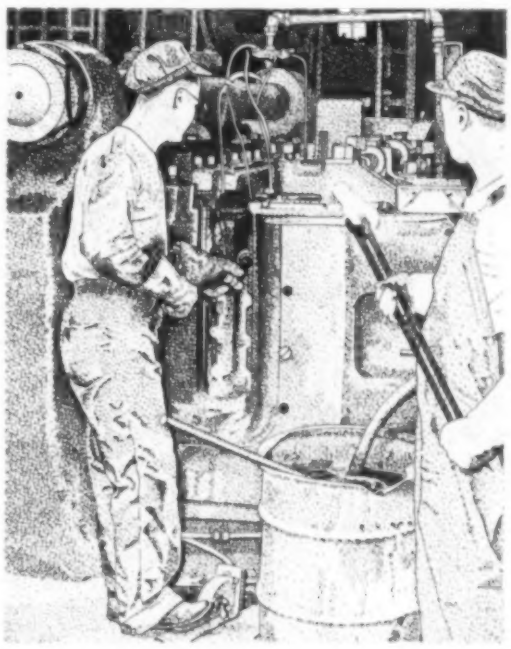
By H. J. Fischbeck
Process Engineer
Pratt & Whitney Aircraft Div.

AIRCRAFT ENGINE forgings are highly refined articles of manufacture, and Pratt & Whitney finds it best to secure all of them from vendors who specialize in this class of work. In fact, we have divided the materials into three categories — heavy steel forgings, light steel forgings, and non-ferrous forgings — and have separate suppliers for each.

Extra care starts in the steel mill. Steels for many parts require that the first, middle, and last ingot in each heat be sampled in the billet and tested variously for composition, segregation and inclusions. Finished bars from the same locations are then tested for tensile strength, grain size, and surface checked for microscopic flaws by magnaflux, not only once but three times, after successively turning to smaller diameter. Each finished bar is marked for heat number, ingot number and position in ingot, and an end disk cut for deep etch test. This extreme care for soundness and quality is supplemented by work at the forge plant where incoming material is checked for microstructure, macro-etch, and hardenability.

Our biggest supplier of large forgings is equipped for making nothing but these large forgings and his system for handling material of this type is especially adapted to the requirements and all material is handled in the same way. All the care lavished on forging machinery, dies, rate of heating stock, temperature control, and trimming to make a quality forging is intensified into "aircraft quality".

Requirements for small forgings for air-



Standard Tolerances for Forgings up to 100 Lb.

Summary of Standards Adopted by Drop Forging Association, 1937

TOLERANCES, within the scope of these standards, shall be either "special" or "regular."

Special tolerances are those particularly noted on the drawings or in the specifications, and apply only to the particular dimension or thing noted. They may state any or all tolerances in any way as occasion may require. Regular tolerances apply in all other cases.

Regular tolerances in general forging practice are known as (*a*) "commercial standard," for general forging practice, or (*b*) if extra close work is desired involving additional expense and care in the production of forgings, "close standard" may be specified.

Class I—Thickness Tolerances

For drop hammer forgings, thickness tolerances shall apply to the overall thickness measured in a direction perpendicular to the fundamental parting plane of the dies.

For upset forgings, thickness tolerances shall apply to the metal actually enclosed and formed by the dies, measured parallel to the direction of travel of the ram.

Thickness Tolerances in Inches

Max. Net Weight	Commercial		Close	
	Minus	Plus	Minus	Plus
0.2	0.008	0.024	0.004	0.012
0.4	0.009	0.027	0.005	0.015
0.6	0.010	0.030	0.005	0.015
0.8	0.011	0.033	0.006	0.018
1	0.012	0.036	0.006	0.018
2	0.015	0.045	0.008	0.024
3	0.017	0.051	0.009	0.027
4	0.018	0.054	0.009	0.027
5	0.019	0.057	0.010	0.030
10	0.022	0.066	0.011	0.033
20	0.026	0.078	0.013	0.039
30	0.030	0.090	0.015	0.045
40	0.034	0.102	0.017	0.051
50	0.038	0.114	0.019	0.057
60	0.042	0.126	0.021	0.063
70	0.046	0.138	0.023	0.069
80	0.050	0.150	0.025	0.075
90	0.054	0.162	0.027	0.081
100	0.058	0.174	0.029	0.087

Class II—Width and Length Tolerances

Width and length tolerances shall be alike, and are classified in three subdivisions (*a*) shrinkage and die wear tolerance, (*b*) mismatching tolerance, (*c*) trimmed size tolerance.

For drop hammer forgings, width and length tolerances shall apply to the metal actually enclosed and formed by the die, as measured parallel to the fundamental parting plane of the dies.

For upset forgings, width and length tolerances shall apply to directions perpendicular to the direction of travel of the ram.

II(a)—Shrinkage and Die Wear Tolerances

See table below. These shall not be applied separately, but only as the sum of the two; they shall be measured in such a way as to eliminate draft or variation in draft. They apply to that part of the forging formed by a single die block, and to no dimension crossing the parting plane.

Shrinkage and Die Wear in Inches

Length or Width	Shrinkage			Die Wear	
	Commercial + or −	Close + or −	Max. Net Weight	Commercial + or −	Close + or −
1 in.	0.003	0.002	1 lb.	0.032	0.016
2 in.	0.006	0.003	3 lb.	0.035	0.018
3 in.	0.009	0.005	5 lb.	0.038	0.019
4 in.	0.012	0.006	7 lb.	0.041	0.021
5 in.	0.015	0.008	9 lb.	0.044	0.022
6 in.	0.018	0.009	11 lb.	0.047	0.024
For each additional inch add	0.003	0.0015	For each additional 2 lb. add	0.003	0.0015
For example:			For example:		
7 in.	0.021	0.011	13 lb.	0.050	0.026
12 in.	0.036	0.018	21 lb.	0.062	0.031
18 in.	0.054	0.027	31 lb.	0.077	0.039
24 in.	0.072	0.036	41 lb.	0.092	0.046
36 in.	0.108	0.054	51 lb.	0.107	0.054
48 in.	0.141	0.072	71 lb.	0.137	0.069
60 in.	0.180	0.090	91 lb.	0.167	0.084

II(b)—Mismatching Tolerance

Mismatching is the displacement of a point in that part of a forging formed by one die block of a pair, from its desired position when located from the part of the forging formed in the other die block of the pair, measured in a projection parallel to the fundamental parting plane of the dies. It does not include any displacement caused by variation in thickness of the forging; mismatching tolerances are independent of and in addition to any others.

Mismatching Tolerance in Inches

Max. Net Weight	Commercial	Close
1 lb.	0.015	0.010
7 lb.	0.018	0.012
13 lb.	0.021	0.014
19 lb.	0.021	0.016
For additional 6 lb. add	0.003	0.002
For example:		
37 lb.	0.033	0.022
55 lb.	0.042	0.028
79 lb.	0.054	0.036
97 lb.	0.063	0.042

II(c)—Trimmed Size Tolerances

The trimmed size shall not be greater nor less than the limiting sizes at the parting plane imposed by the sum of the draft angle tolerances and the shrinkage and die wear tolerances.

Class III—Draft Angle Tolerances in Degrees

	Drop Forgings		Upset Forgings	
	Outside	Inside Holes	Outside	Inside Holes
Nominal angle	7	7 or 10	3	5
Commercial limits	0 to 10	0 to 13	0 to 5	0 to 8
Close limits	0 to 8	0 to 8	0 to 4	0 to 7

Class IV—Quantity Tolerances

Any quantity shipped within the quoted limits of over-run or under-run shall be considered as completing each release or part shipment of an order Limits are as follows:

Quantity Tolerances

Number on Order	Over-run	Under-run
1 to 2	1 piece	0
3 to 5	2 pieces	1 piece
6 to 19	3 pieces	1 piece
20 to 29	4 pieces	2 pieces
30 to 39	5 pieces	2 pieces
40 to 49	6 pieces	3 pieces
50 to 59	7 pieces	3 pieces
60 to 69	8 pieces	4 pieces
70 to 79	9 pieces	4 pieces
80 to 99	10 pieces	5 pieces
100 to 199	10%	5.0%
200 to 299	9%	4.5%
300 to 599	8%	4.0%
600 to 1,249	7%	3.5%
1,250 to 2,999	6%	3.0%
3,000 to 9,999	5%	2.5%
10,000 to 39,999	4%	2.0%
40,000 to 299,999	3%	1.5%
300,000+	2%	1.0%

Class V—Fillet and Corner Tolerances

Fillet and corner tolerances apply to all intersecting surfaces even though drawings or models indicate sharp corners. If such drawings or models have or indicate (even though actual dimensions are not specified) fillet or corner dimensions of larger radii than the following standards, such larger dimensions shall be considered as actually specified and the tolerances shall be "special tolerances."

Where a corner tolerance applies on the meeting of two drafted surfaces, the tolerance shall apply to the narrow end of such meeting and the radius will increase toward the wide end. The total increase in the radius will equal the length of the drafted surface in inches, multiplied by the tangent of the nominal draft angle.

Fillet and Corner Tolerances

Max. Net Weight	Commercial	Close
0.3 lb.	3/32	3/64
1 lb.	1/8	1/16
3 lb.	5/32	5/64
10 lb.	3/16	3/32
30 lb.	7/32	7/64
100 lb.	1/4	1/8

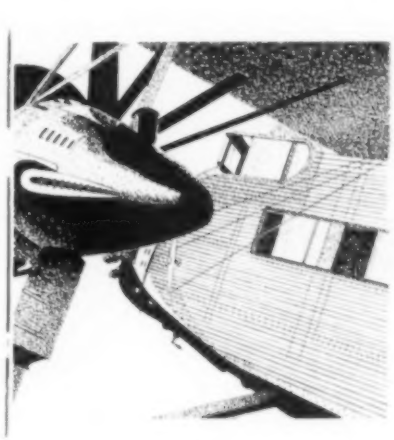
craft engines are not so closely restricted and sources of supply are more numerous. But again, we have found it advisable to buy the greater portion of the small forgings from one vendor who is experienced in making small forgings of aircraft quality. The system of control here is not so elaborate for each individual forging but is carried out to approximately the same extent for each lot or group of pieces.

We check our large forgings 100% for most of the physical properties, while our small forgings have complete checks on only a small percentage of the pieces received. While some of this minute care may appear to be superfluous, it undoubtedly is a prime factor in the ability of Americans to build aircraft engines of unsurpassed reliability.

Forgings for Aircraft Structures

By S. K. Oliver
Metallurgist, Douglas Aircraft Co., Inc.

INCREASED foreign demands for American built planes, national preparedness for defense, and the upward trend in commercial air transport, have resulted in a complete orientation of specifications for processing and fabricating materials in the aircraft industry. Forgings and forging materials are just two of the major items which are experiencing changes as a result of this increased activity.



At the present time the ratio of ferrous to non-ferrous forgings for aircraft structures (not including engines) is approximately one to four, and the ferrous materials used for aircraft drop hammer or pressed forgings can be classed in the following manner:

Approximately 90% of them are of the chrome-molybdenum S.A.E. 4130 type of material, while the remaining 10% are made up of medium straight carbon S.A.E. 1045 steels, medium carbon alloy steels (3½% nickel and chrome-vanadium types), and corrosion resistant material (stainless steel). The trend in future designs indicates an increase in the use of stainless.

Whether this grouping of materials "just happened" or was carefully planned cannot be determined. Compared to other industries the aviation industry has done a good job in simplifying and minimizing the number of ferrous materials used for drop and press forgings.

The non-ferrous forgings (approximately 95% of which are aluminum alloys) have, up to now, enjoyed the largest share of designers' and builders' material requirements, outnumbering steel four to one, as mentioned above. It is the consensus of designers in the Los Angeles region that with increased production of airplanes and accessories the four to one ratio will become more nearly balanced toward the ferrous materials. Several factors that will contribute to this change will be the redesign of large numbers of structural parts now built of ferrous sheets, bars and extrusions (a method entailing high tool and labor cost) to drop hammer or press forgings.

The designers' requirements of greater strength and reliability with low weight can now be met by precision drop hammer forgings in alloy and stainless steels.

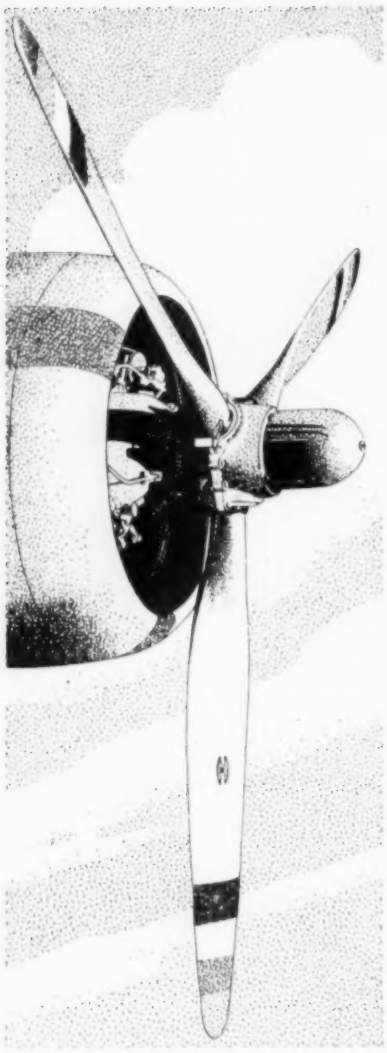
In the non-ferrous field (which up to the present has been dominated by aluminum alloys) the spotlight has swung around and is now focused on a new forging material, magnesium alloy. Such forgings are finding an ever increasing value to the aircraft industry because they are about 40% lighter in weight than aluminum, yet are strong, have good fatigue resistance, and exceptional ease of machining.

Magnesium alloys have been developed which are suitable for drop hammer forgings as well as press forgings. The alloys suitable for drop hammer forgings are somewhat lower in cost and the forgings can be made to closer dimensions than press forgings, but they do not develop as high strength.

Aluminum Aircraft Forgings

By L. W. Davis
Aluminum Co. of America

DURING THE PAST YEAR the demand for aluminum alloy forgings has increased more rapidly than ever before in the history of the industry. With the opening of the war in Europe, the aircraft industry in this country



entered upon a period of rapid expansion. This not only increased the demand for parts formerly produced as forgings, but also resulted in the introduction of many new forgings into airplane structures. The production of larger numbers of planes of the same model justified the expense of dies and brought about the adoption of forgings in places where castings and welded structures had been used in the past. The net result has been that the production of aluminum forgings is now approximately at four times the rate it was during the summer of 1939.

A change has been taking place gradually in the type of structural fittings produced for airplanes. Several years ago it was general practice for aircraft designers to specify small forged aluminum fittings, which were joined by other types of structural material. Then a group of fittings placed close together were redesigned so that a single larger forging could be used in their place. This has resulted in a steady increase in the size of forged fittings until this year entire wing supports are being produced as a single forging.

This change in the physical dimensions of forged aircraft structural parts has been made possible only by the use of larger and heavier forging equipment, and some of the largest hammers ever built are now in use for this purpose. More of these large hammers are being placed in service and it is to be expected that the use of large forgings will be extended to other commercial fields.

Another development during the past year has been the much greater use of hydraulic presses for various forging operations. This type of equipment is used for breakdown and cogging operations on alloy ingots which do not lend themselves readily to rolling. It is also advantageous in working material of large cross-section, where the effect of the work must penetrate to the center of the mass. This use of hydraulic presses is analogous to the practice in heavy steel forgings and has enabled the industry to develop and put into production alloys with higher mechanical properties than were ever before available.

One of these new alloys has proven particularly adaptable to airplane propeller production and thousands of propeller blades made from it are now in service. It is believed that in the course of years this alloy will demonstrate its clear superiority over materials previously used.

The use of small pressings, one of the newer forms of aluminum forgings, has continued to expand, particularly in the aircraft field. Their close dimensional tolerances, coupled with low machining costs brought about by these tolerances, have made this type of forging particularly attractive for many parts such as pipe fittings and control components.

Technical advances, such as improvements in preheating and heat treating methods and equipment, have kept pace with the mechanical advances noted, so that today the quality as well as the quantity of aluminum alloy forgings in airplanes is on a higher level than ever before.

Fast Presses

By E. V. Crane
Engineering Department, E. W. Bliss Co.

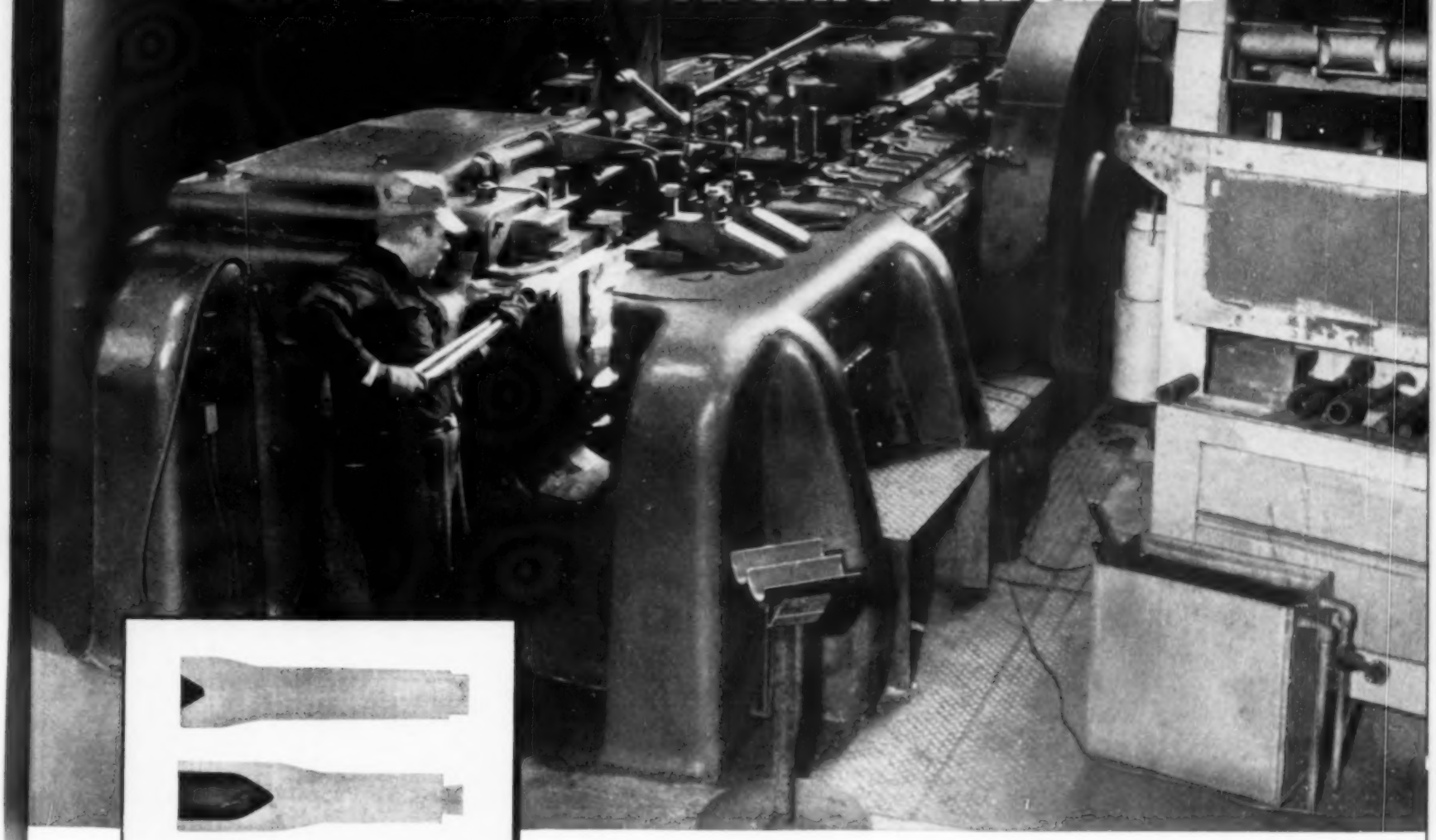
SELF-CONTAINED, high speed, hydraulic presses are settling down to a proper place in the stamping industry, in keeping with their advantages and their limitations. The best cycles of operation are quite economical and sound, and give speeds approaching those of modern mechanical presses. Positive control of the down stroke, close fitting gibs, and effective purging of entrained air are now accomplished facts in our lines of equipment.

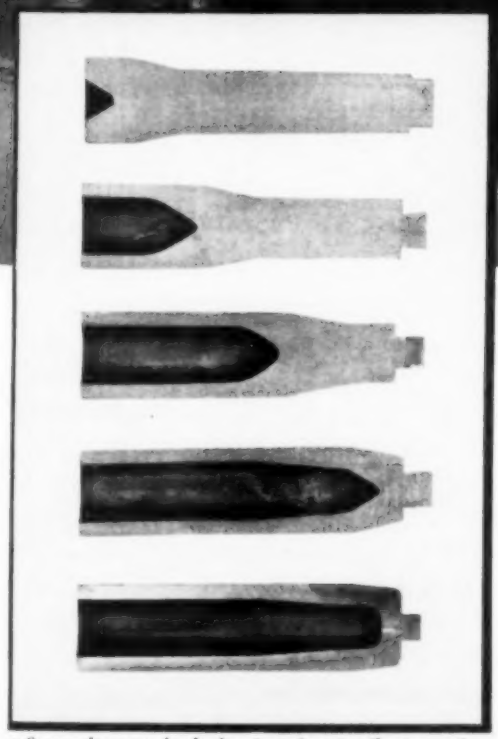
Enclosed models of fast mechanical presses trend to the streamlining of easily removable covers or hoods and the use of split main bearings, as well as split intermediate and driveshaft bearings for easy maintenance.

Governmental requirements for large quantities of small parts have given further impetus to the use of high production automatic presses, which complete the parts at one handling from coil stock.

Latest Practice –

IN FORGING SHELLS ON AN ACME "XN" 5-INCH FORGING MACHINE





• *Successive steps in the forging of projectiles in an Acme XN forging machine.*

• Here is one of the 5-inch ACME XN forging machines at work forging projectiles for our own preparedness program. Forging practice has advanced during recent years to the point that so great a degree of accuracy can be maintained in steady production that it is no longer necessary to machine the internal surfaces of the shell. Specified tolerances on shell bores, minus nothing, plus .020", are easily maintained.

This ACME XN forging machine will produce 75-mm. shells at the rate of 75 an hour. It will forge 105-mm. shells with change of dies. This powerful machine's frame, a one-piece steel casting, accounts for over 100,000 lbs. of the total weight of 190,000 lbs. Five cavity dies are used to forge the shells. Pilot holes in plate at front of fixed die serve to insure a true center for punches and also act as a stripper.

This machine is now equipped with a manipulator, (*patents applied for*) developed by Acme engineers to sustain entire weight of the forging, thereby eliminating fatigue of the operator. It transfers and locates stock mechanically in each groove of the dies progressively, thereby increasing production 10% to 15%.

All ACME XN forging machines have the eccentric type main shaft, fully suspended header slide and suspended die slide, with double toggles. A catalog fully describing them will be sent on request.

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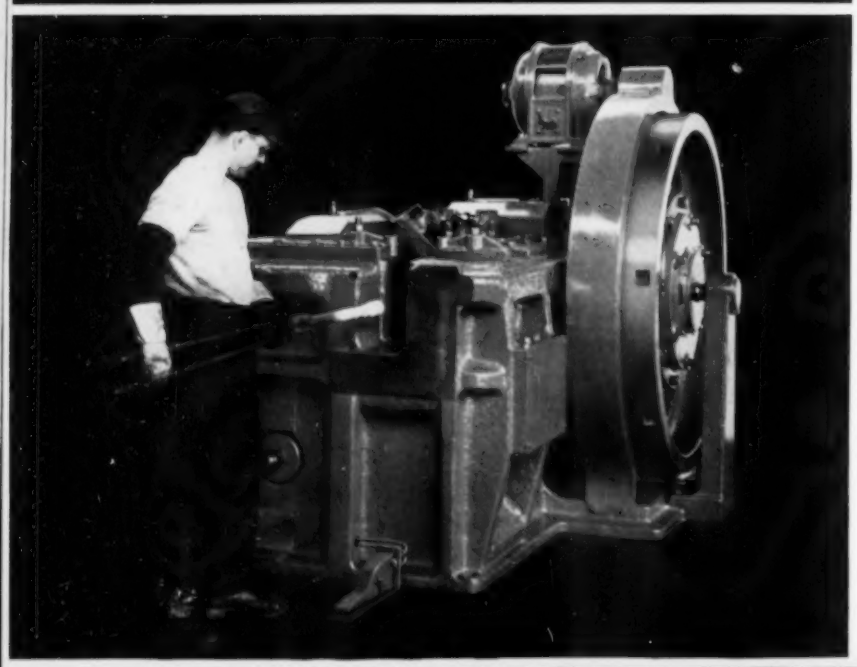

AJAX FORGING MACHINERY provides unusual facilities for forging a great variety of shapes

Metals subjected to compression force, as when forging in confining die impressions, offer the maximum in grain refinement and toughness. In the forging process, grain flow is controlled, and higher physical properties are attained. By forging, it is possible to obtain a range of specific "quality advantages" which are not otherwise obtainable.

Speedier production of forgings, closer tolerances, substantial savings of material, and reductions in cost, are common benefits realized when forgings are fabricated with Ajax Forging Machinery.

Ajax Upsetting Forging Machines

Seldom is so high a penalty placed upon the use of obsolete equipment as in the use of upsetting equipment, where Ajax Air Clutch Forging Machines are consistently setting and maintaining new production records on all types of upset forgings weighing from a few ounces to many pounds. Smooth, cushioned starting at high speed makes possible the completion of many multi-operation forgings at a single heat, which would otherwise require re-heating.

As one part after another, whether of simple or complex design, whether weighing a few ounces or many pounds, has been successfully forged in Ajax Air Clutch Forging Machines, it has become practical to upset forge an ever increasing variety of shapes and sizes.

In Ajax Air Clutch Forging Machines, the unyielding rigidity of the one-piece, solid steel frame, with continuous crankshaft housing, withstands the tremendous pressures of gripping and heading. This results in unusually accurate die and tool alignment and consistently uniform, accurately matched forgings. Seemingly difficult operations are rendered easy with the precision matching of all die elements in these machines. Uniformity

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of forging dimensions is limited practically only by the accuracy to which dies can be maintained on production work. On many forgings, the machining allowances are little more than is required for removing the decarburized skin.

These heavier, more powerful, faster machines, ranging in size from 1 inch to 8 inches, are producing an ever-increasing variety of shapes and sizes of forgings for industrial equipment, automotive, aircraft, ordnance, navy and diesel construction.

Write for Bulletin 65-A describing sizes 1-inch to 8-inch.

Ajax Solid Frame Forging Presses

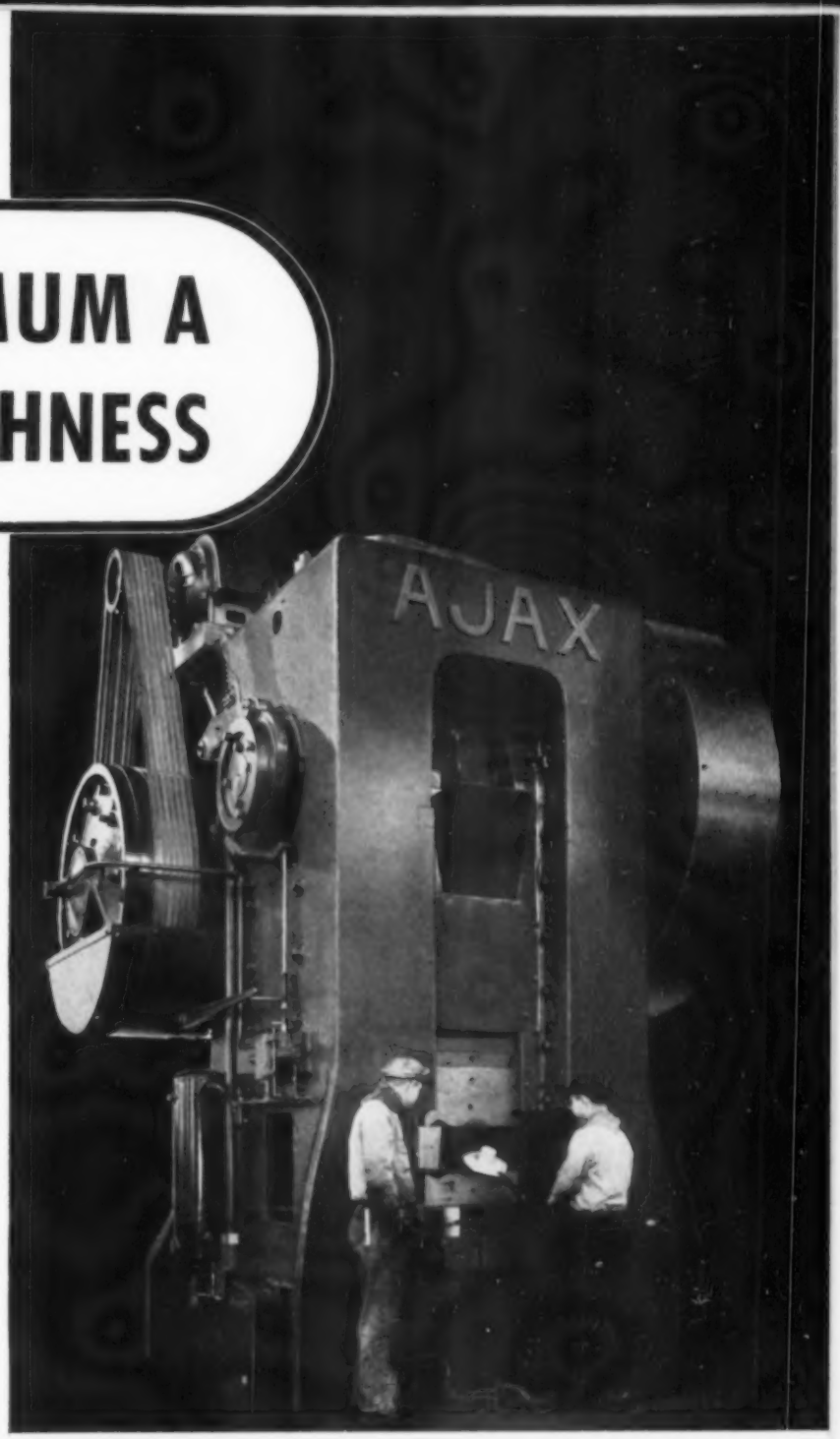
Ajax Solid Frame Forging Presses, capacities 500 to 2,000 tons, for accurate high speed forging, have greatly widened the field of practical press forgings. They are making certain classes of forgings, both hot and cold, of ferrous and non-ferrous metals, with a degree of accuracy and economy far surpassing other types of forging equipment. The advent of these presses removed restrictions which had handicapped progress on the older, slower, less rigid, and less accurate crank, toggle and hydraulic presses.

Symmetrical forgings such as gears, driving flanges, hubs, and rock drills are produced from blanks of round or round-cornered square stock sheared to length and up-ended between the dies.

The extrusion process is employed for cup or shell-type forgings, also forgings with large heads and slender shanks, like poppet valves, when the volumetric relation of head and shank would make upset forging difficult.

Stock may be forged flat-wise to produce forgings in direct competition with hammer forgings. Required variations in cross-section, when not too great, may be obtained by preliminary fullering operations. Where the cross-sections vary excessively, blanks may be prepared by pre-rolling in Ajax Wide Adjusting Forging Rolls, and press forged at the same heat as rolled.

These Ajax Solid Frame Forging Presses have twice the speed of the fastest presses of equal tonnage ten years ago. Their high speeds result in unforeseen advantages and economies in fabricating press forgings. Write for Bulletin No. 75, which completely describes these presses and their greater production possibilities.



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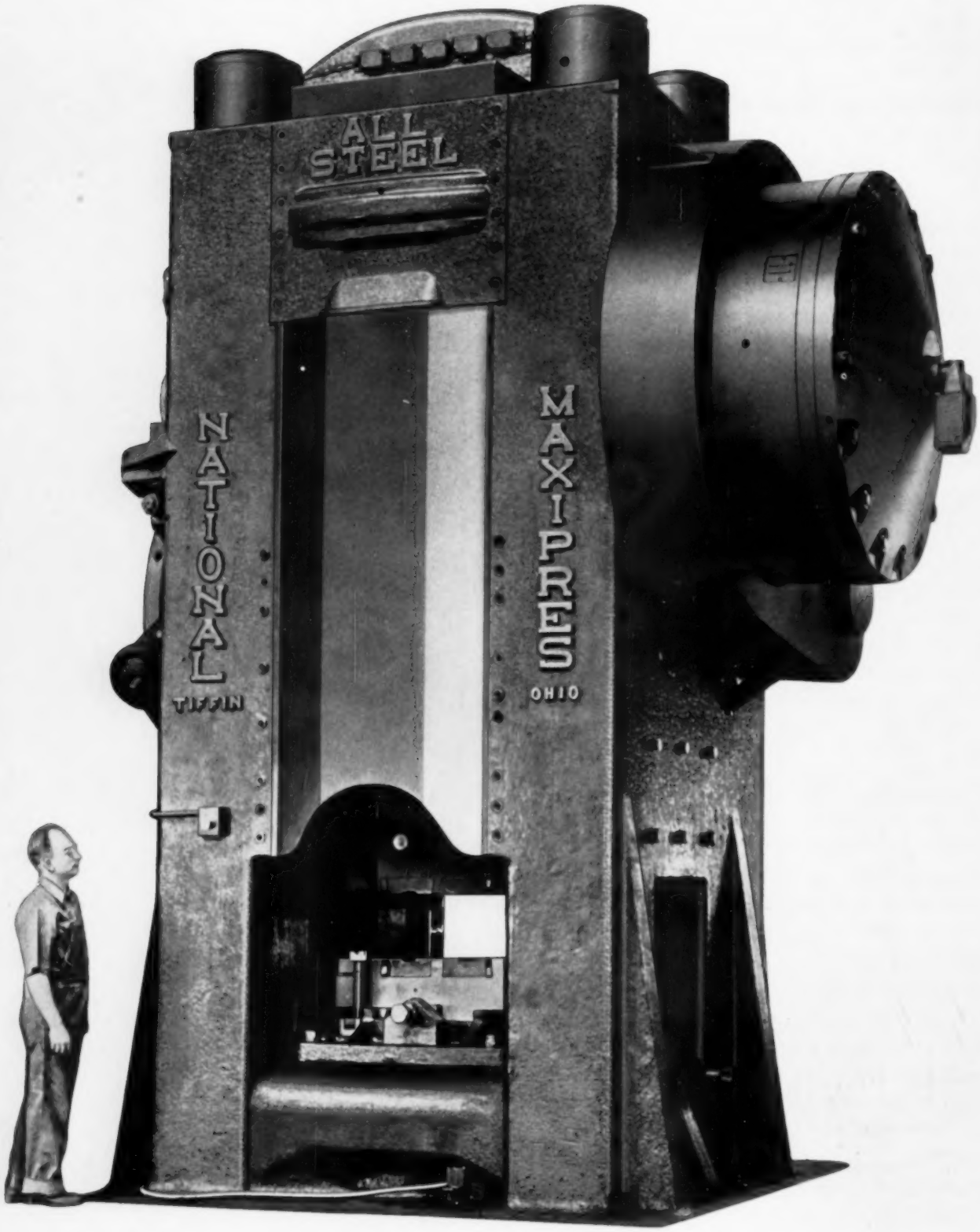

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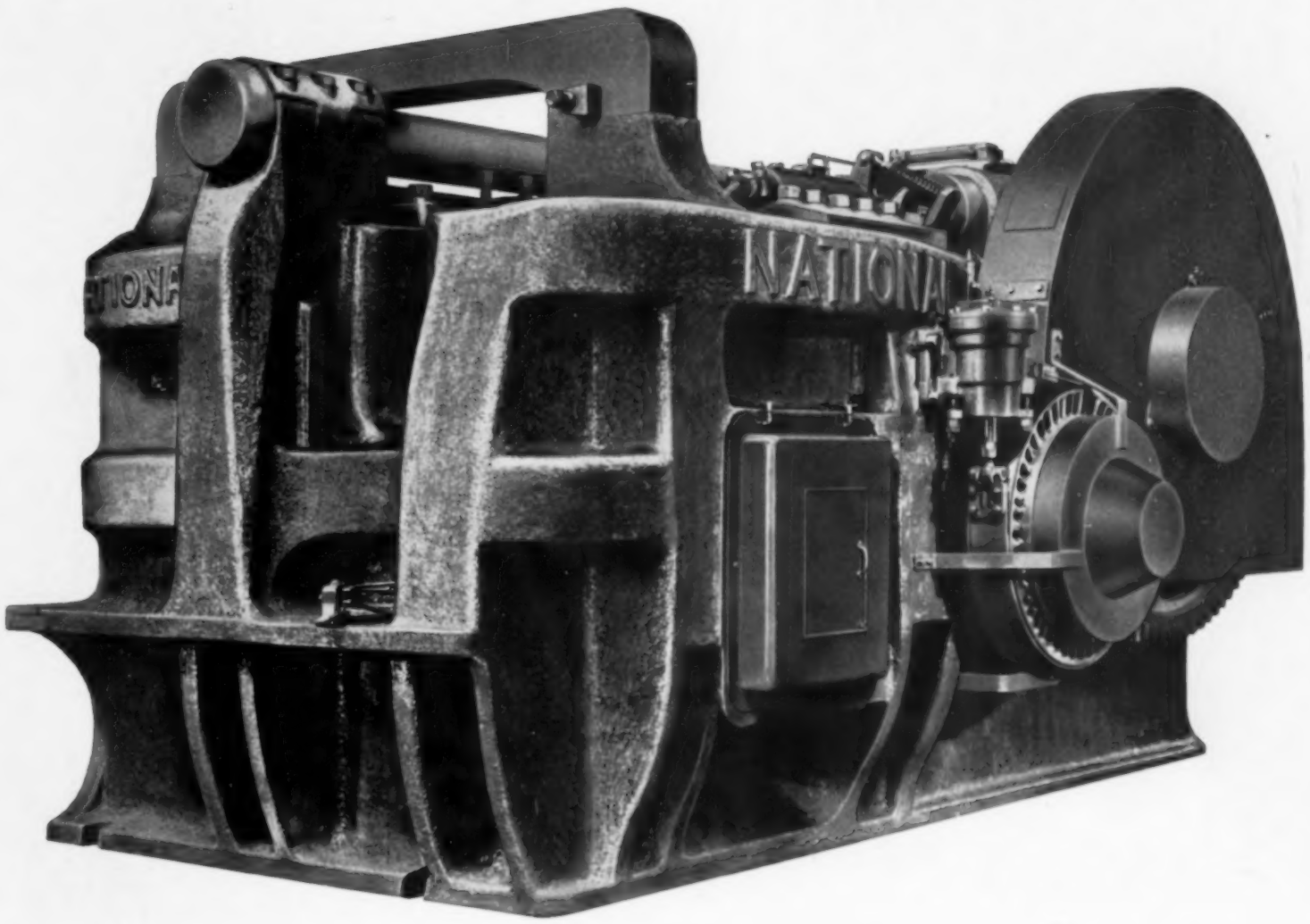

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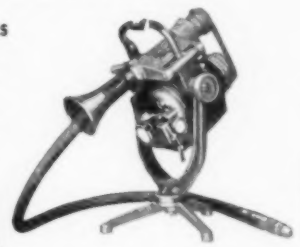

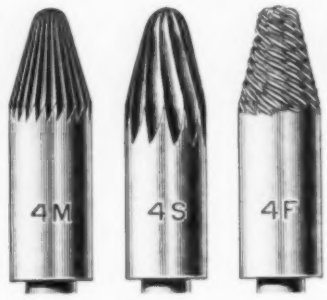

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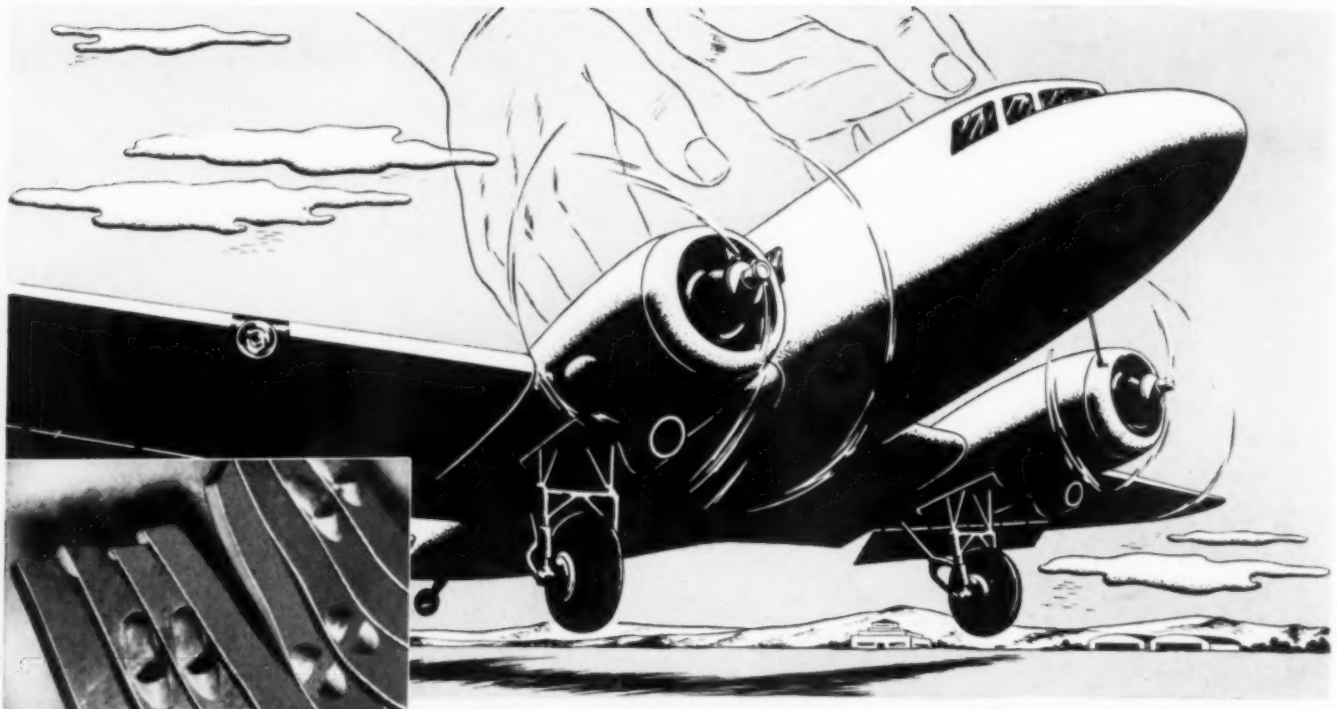
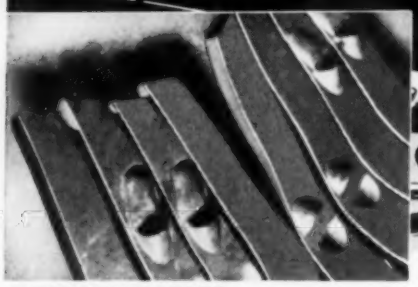
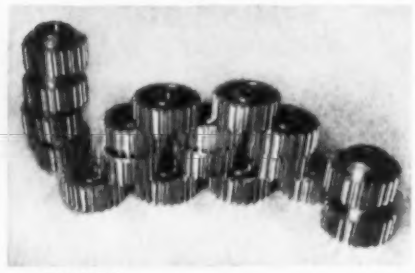




FORMING DIES . . .
— where AMPCO METAL'S hardness, its resistance to pitting, wear and impact result in exceptional accuracy and long life.



GEARS . . .
The toughness and wear resistance typical of AMPCO METAL recommends it for all types of gears, ranging from a fraction of a pound to hundreds of pounds each.

PICKLING EQUIPMENT . . .
AMPCO METAL'S great resistance to corrosion makes it widely used in this type of service, and wherever else corrosion is a problem.

BEARINGS . . .
AMPCO METAL is probably more widely used for bearing service than any other bronze. It is noted for its stubborn resistance to wear, "squashing out" and shock loads.

Like *Protective Hands* for a SAFE LANDING!

A critical moment — as plane and ground meet. If vagaries of wind and timing make the meeting a rough one, the landing gear must safely absorb severe impact.

At points of greatest stress and shock in the landing gear of plane after plane, AMPCO METAL is used . . . undeniable proof of the greater strength and longer wearing qualities of this dependable bronze.

SPECIFIED *for the* "TOUGH" JOBS

In other industries, as in aviation, you'll find AMPCO METAL widely used wherever exceptional durability and resistance to impact, fatigue, wear and corrosion are required. It enjoys a unique reputation as "the metal that makes good when all others fail."

Have You a Problem of "Metal Failure"?

Maybe AMPCO METAL can master a troublesome job for you. It's made in many grades and forms. Tell our engineering staff what you're up against, and they'll be glad to supply complete data and recommendations. There's no obligation. Write

AMPCO METAL, INC., Dept. MP-10, Milwaukee, Wisconsin

At the National Metal Show . . . AMPCO SPACE Y-26

Non-Ferrous Metals

Strategic Metals
(Other Than Manganese and Chromium)*

By S. M. Shelton
Supervising Engineer, Ore-Dressing Section
Metallurgical Division, Bureau of Mines

STRATEGIC METALS represent a strikingly small percentage of our national metal requirements, but strategic classification by definition means national deficiency, and adequate provision for emergency or national defense can tolerate no deficiency, however small.

Nickel, tin, antimony, tungsten, and mercury are designated with manganese and chromium as strategic metals by the Army and Navy Munitions Board.

Nickel has grown from an interesting minor metal to a necessity, but domestic reserves have not been established. Our supply is imported (mostly as matte, ore, and alloy ingots) from the Sudbury and Cobalt districts of Canada, which produce 90% of the world's nickel.

Tin is probably even less abundant than nickel in domestic deposits. Malaya has supplied more than half of our requirements, with some 20% smelted in Great Britain from Bolivian and Nigerian ores.

The position of *antimony* is similar to that of nickel, in that the major source of supply is in a neighboring country. Since 1930 Mexico has replaced China in providing our antimony, and in recent years Mexico has satisfied more than 60% of our primary antimony requirements. Imported ore is smelted at Laredo, Tex., and at Los Angeles. Domestic production of primary antimony is small, but may be increased. The Mexican reserves and certainty of supply of antimony are not so well established as those of Canadian sources of nickel.

Fortunately, we have domestic reserves of indispensable *tungsten* to supplant the dwindling supplies from China. Mines in Nevada, California, and Colorado, with other smaller deposits, probably can supply more than half our requirements.

Mercury is produced domestically in important quantities, and large reserves are known. However, the tenor of the ores has reached low levels. Improved technology and high price levels are needed to make us independent of the principal world producers in Spain and Italy.

Historically, nations have attempted to provide needed materials by international treaty or agreement, by acquisition of territorial sources of supply, by encouraging the development of domestic resources, by the purchase of adequate stock piles, and the invention of substitutes.

Domestic deposits of ores of all seven strategic metals warrant careful investigative and development work. Present secondary recoveries of tin and antimony furnish appreciable percentages of supply, but submarginal secondary supplies deserve study. Secondary supplies of nickel in discarded automobiles and other scrap will be important if the need for nickel becomes acute.

A comprehensive investigation of substitutes for tin, antimony, and mercury is needed to control consumption in times of emergency.

More extensive mineral development work, with improved methods of ore dressing and smelting, will insure a supply of tungsten and mercury for pressing domestic needs.

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New Uses of the Minor Metals

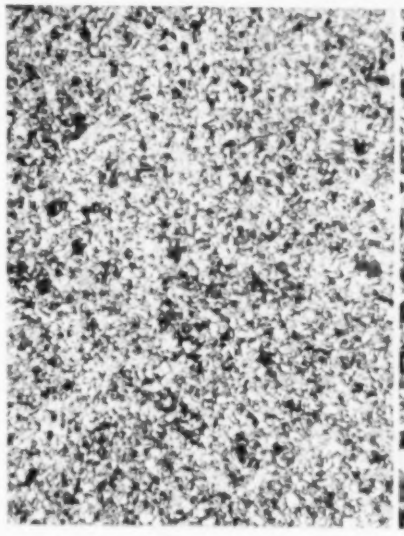
By C. L. Mantell
Consulting Engineer

SOME sketchy notes on metals, less well known and widely used, may be of interest, although consideration must necessarily be brief:

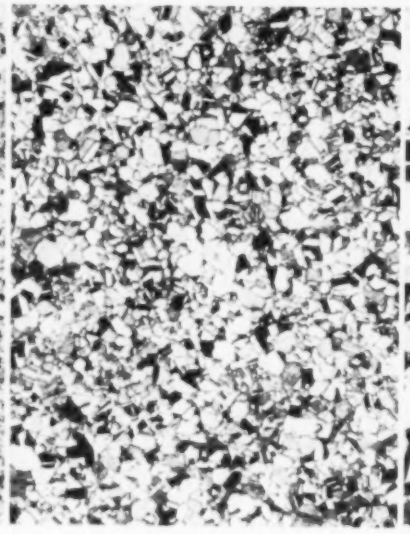
Barium — The production of barium is on a pilot plant or experimental scale to satisfy the relatively small poundage consumed, chiefly by

Standards for Estimating Grain Size (Non-Ferrous)

American Society for Testing Materials Standard E2-39T (copyrighted) for annealed materials such as brass, bronze, nickel silver
Actual diameter of average grain is noted; Magnification of micros: 75 ×



0.010 mm.

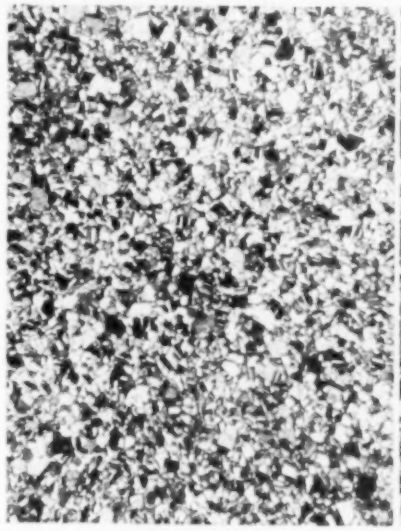


0.025 mm.

0.045 mm.

0.090 mm.

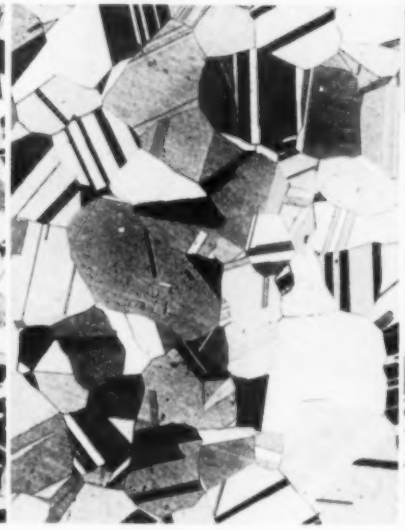
0.150 mm.



0.015 mm.

0.035 mm.

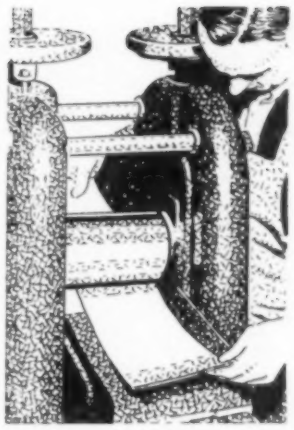
0.065 mm.



0.120 mm.

0.200 mm.

the manufacturers of radio, vacuum, and thermionic tubes. In this connection barium and its alloys are employed as "getters", along with lithium, potassium, and calcium.



Calcium — In contrast to the situation previously existing where (to all intents and purposes) the metal was imported, calcium is now an American product derived from calcium salts, particularly the chloride, by electrolytic furnace operations. Calcium continues to find new uses *(a)* as a deoxidizer and alloying agent for non-ferrous metals such as copper and lead, *(b)* in the preparation of high temperature, high resistance nickel-chromium and nickel-chromium-iron alloys, *(c)* in the form of its hydrides as a reducing agent for the production of rare metals such as titanium, vanadium, uranium, and zirconium. A considerable portion of the patent literature has been devoted to aluminum and aluminum-magnesium alloys containing calcium as a modifying agent.

Indium — Metallurgically, indium has been limited to platings and diffused platings on cadmium and other alloy bearings, as an alloying constituent in jewelry metals, and in silver for imparting tarnish resistance.

Lithium — Although there has been a large amount of metallurgical work done on lithium and its alloys, the quantity used for this purpose in connection with both the oxidation and alloying is still small. Although the lithium-copper alloys are of considerable interest, their production is still on the laboratory scale. Considerable interest is now being shown in lithium and its compounds for producing non-scaling atmospheres in heat treating furnaces.

Platinum — Of metallurgical interest has been the search for new applications of platinum, particularly in the form of platinum clad nickel and steels of the corrosion resistant type. Such bi-metals are used in the construction of high grade equipment in the chemical and pharmaceutical industries.

Potassium — Most of the potassium metal has been imported and small stocks exist. While many uses have been proposed, the only important application is in the form of pellets for use in vacuum tubes.

Rhodium — Rhodium finds its principal use as a platinum alloying agent, which in turn is used as a catalytic material for ammonia oxidation, or as a plating to impart corrosion resistance.

Ruthenium — With increasing prices of iridium, ruthenium has been used to a certain extent as a hardener for platinum.

Sodium — With an annual production above that of magnesium, sodium can hardly be called a minor metal any longer. Perhaps its metallurgical aspects are hidden behind its chemical uses, where the metal serves as an essential material in the preparation of tetra-ethyl-lead, sodium oxides and peroxides, cyanides and related products. Tank-car shipments of the metal are now accepted as an everyday and usual occurrence.

Tantalum — In the form of its cemented carbides, tantalum finds increasing application in wire drawing dies, cutting tools, and wear resistant parts, either alone or in combination with the carbides of tungsten or titanium. Tantalum has been gaining increasing usage as a material of construction for chemical apparatus, particularly as heat transfer equipment, in bayonet heaters, hydrochloric acid reaction apparatus, and as spinnerets for synthetic textile threads and fibers.

Tellurium and Selenium — Metallurgically, the major application of tellurium is as tellurium-lead, where the percentage required is small. There has been some use with lamps using liquid tellurium where a continuous instead of a line spectrum is desirable. Along with selenium, tellurium has found some application in copper and copper alloys to improve machinability. Selenium rectifiers have been developed for electric power sources for plating tanks and other heavy duty operations. It is stated that they will stand high overloads without deterioration. Both metals have been used to a small extent as modifying agents in steels of the corrosion resistant type.

Soft Solders

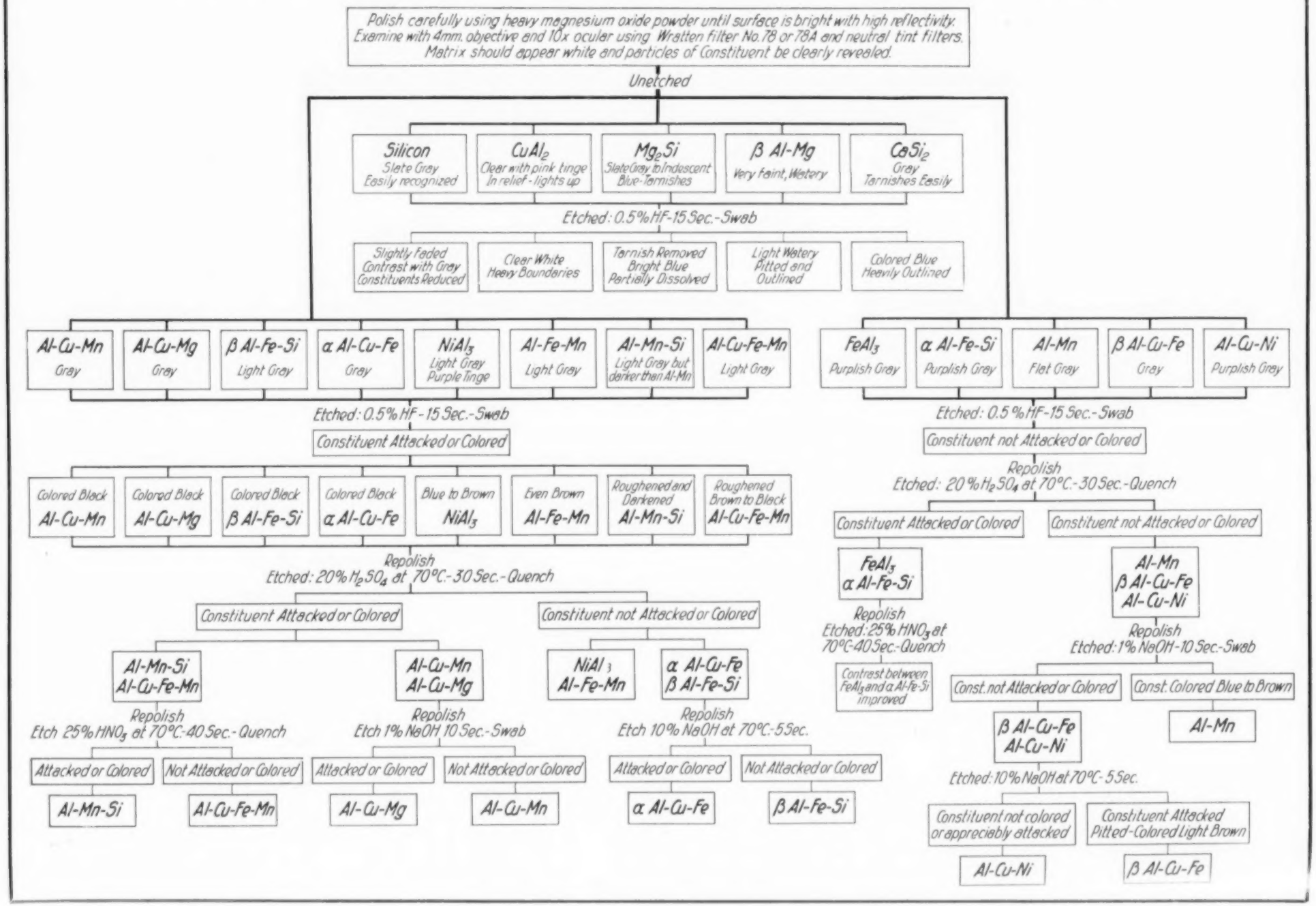
By George O. Hiers
Research Laboratories, National Lead Co.

SOFT SOLDERS are considered to be binary lead-tin alloys or ternary lead-tin-antimony alloys, in which the tin averages about 38%. The binary alloys are in more extensive use.

For the free-flowing qualities demanded by

Identification of Constituents in Commercial Aluminum Alloys

By F. Keller and G. W. Wilcox, Aluminum Research Laboratories (After Dix and Keith, with additions)



the piece worker who uses soldering irons (made of copper) for making joints by applying the metal to seams, 50% tin, 50% lead solder is most popular. Undoubtedly this is due to the composition being largely eutectic and also due to the nature of its "alloyability" with the parts soldered.

Regardless of the type of soldering, attempts are being made to use solders with less than the customary amount of tin, largely because of the high price of tin compared with lead. To effect economies by such practice, the following factors must be considered:

1. Strength and quality of joint.
2. Weight of solder applied.
3. Cost of application.
4. Cost of solder.

A good wiping solder may contain 40% tin and 60% lead. As shown by the Bell Telephone Laboratories, another good wiping solder contains 24% tin, 9% cadmium and 67% lead. Under certain market conditions the latter alloy is preferable.

Investigations have led to the development of new commercial wiping and body solders which have improved working properties. Besides the use of lead and tin, small amounts of other elements are added to cause the semi-liquid solder to be more workable when applied on account of a finer grain size.

In the range between 600° and 1000° F. there is need for inexpensive solders with appreciable strength and ductility but with lower melting points than the brazing solders. Possibly such solders, if found, might not be called "soft" solders. At the present time silver solders partly meet the requirement.

Manganese of High Purity

By K. M. Leute
President, Electro Manganese Corp.

THE ELECTROLYTIC METHOD of producing manganese metal has been advanced as one of the most promising processes for the utilization of great tonnages of low grade American ores, and a commercial plant is now in operation at Knoxville, Tenn.

Electrolytic manganese had its inception in work of the U. S. Bureau of Mines. The Electro Manganese Corp. undertook to commercialize this work in October 1938, and a plant designed to produce 5000 lb. a day was completed in May 1939. The first attempts at production were unsuccessful, due to a failure in the translation of laboratory results into large scale operation. Within a few months these difficulties had been sufficiently corrected to permit the production of 200 to 300 lb. per day. Operation and improvement have since been practically continuous, so that production is now in excess of 2000 lb. per day and is being further augmented. Total production to date has been approximately 300,000 lb. of 99.9+% manganese metal, in the form of cathode chips (broken sections of the brittle cathodes, ⅛ to ¼-in. thick) packed in 250-lb. steel drums. This entire production has been consumed in an acceptable manner in the non-ferrous industry in the production of copper, nickel, zinc and aluminum alloys, as well as in the ferrous field of specialty alloys, and stainless steels and irons.

Prices are now competitive with manganese metal from electrothermal or aluminothermic processes, while its quality definitely exceeds these 96 to 98% materials.

Indications for the future are that gradually increasing consumption and corresponding expansion in production will result in carbon-free manganese being made available to the steel industry for use in low carbon steels at an acceptable price.

A considerable amount of study by a number of workers and organizations has been directed to the use of this really new metal in old alloys, as well as in new alloys having manganese as an important or major constituent. These were discussed by R. S. Dean in Metal Progress of October 1939.

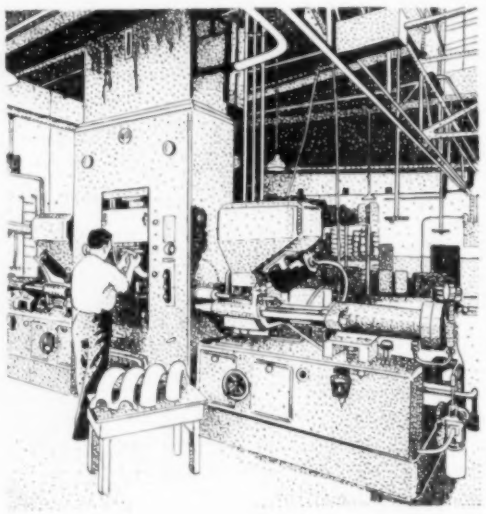
Further development on the producing side involves large amounts of work in hydrometallurgy, electro-winning and engineering as well as further refinement of manufacturing processes, all of which are reasonably to be anticipated.

Problems Connected With the Fabrication of Metal Parts From Powders

By Harold E. Hall
General Manager, Metals Disintegrating Co.

IN THE FIELD of molded and sintered products major interest has shifted in the past several years in what might be regarded as a revolutionary way. In the past, powder metallurgy has been almost entirely concerned with the making of parts difficult or impossible to

make in any other manner. In this new trend, powder metallurgy displaces established, conventional methods of manufacture. Here the powder method's main claim is that it can do the job at a lower cost. Under these circumstances it might be said that within the past few years the powder method has come of age and, having established itself as a sound method of fabrication, has now begun to challenge the older recognized methods on the single point of economy.



The industry, including the powder manufacturer as well as the powder user, now finds itself confronted with the problem of turning out these new objects at a minimum cost and of a quality matching or surpassing that of competitive processes. If the powder process is to invade the domain of these established and time tested methods, much work must be done by all parties concerned with the manufacture and utilization of the powder. Cheaper iron parts made from powders have already begun to appear, but so far they are few in number compared with the possibilities.

The selling price of any metal powder is a factor limiting the extent to which the new method may successfully compete with older ones. But, the price of a powder cannot be considered apart from its quality. A cheap powder which does not have good molding characteristics simply transfers a cost burden from the powder manufacturer to the fabricator, forcing him to add to his final cost, since he must make up in some way for the shortcomings of his raw material in order to produce a quality product.

One major problem of powder metallurgy today is the betterment of the physical properties of its products. Increased molding pressure is an obvious direction in which to turn. Presses would then have to be larger and more expensive. Since the type of product of which we speak will have to be made at high speed, the press manufacturer will certainly have a problem in designing this more powerful equipment to turn out these pieces at no, or only a little, increase in cost. So, also, with the dies; these expensive items would be still more expensive if higher molding pressures shorten their life.

A further complication for iron compacts is that for ultimate exploitation of this low cost field more complicated shapes will have to be fabricated. This throws another major job on press and die makers to make both dies and presses capable of doing the unusual and difficult tasks even now being asked of them. Of course, these things will have to be done at costs which will still permit the pieces to be made very cheaply. Furnaces will also come in for scrutiny, as the sintering of iron compacts requires higher temperatures than those usual up to now. Problems incidental to fabrication of the alloy steels, when they shall come along, may also confront the furnace manufacturers with some new problems.

Considering the metal powders themselves, if two different powders were available, one of which was soft and malleable, the other being what we know as a "hard" powder, it is obvious that lower molding pressures could be used with the softer powder than with the harder, and if dies also are considered, the physical characteristics of the powder are seen to be of great importance to the user.

Finally, the powder metallurgist will have problems added to those he now considers worrisome enough — one of the chief of these being the holding of dimensions within specified limits while sintering the briquette or compact. Commercial production of parts where maximum physical properties are demanded has thus not yet arrived on the scene, and special problems in the ferrous field are to be anticipated in this connection.

Die Casting as a Production Aid

By Donald L. Colwell
Paragon Die Casting Co.

SEVERAL YEARS AGO the writer pointed out in this journal that the tremendous improvement in the stability of the zinc alloys made die castings an important engineering material. The great increase in the use of die castings

(particularly zinc base die castings) has emphasized the growing confidence of engineering departments the whole country over in a method of volume production that offers quality with great economies.

Since that article was written the total amount of zinc used in die casting has increased more than four fold, and the ratio of the zinc used in die casting to the total zinc consumption has more than doubled. The 1941 automobiles and washing machines, just to mention two large outlets, will use more zinc die castings per unit than at any time in history.

There are several reasons for the greater confidence in zinc die castings. In the first place, the alloy improvement mentioned above has practically eliminated the old fears of deterioration. Finishing methods have also been perfected, so that the metal may be better protected from various unusually corrosive attacks. Although the zinc alloys are generally more resistant to atmospheric corrosion than ordinary iron or steel, they have often been electroplated for appearance's sake. Both the methods of plating and specifications for the

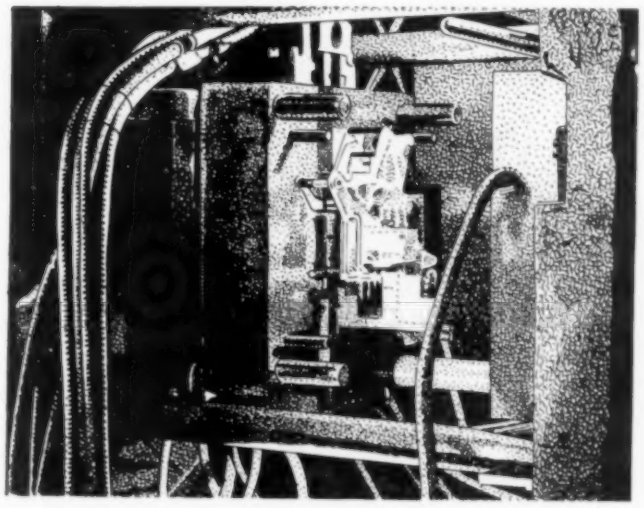


plate have been markedly improved during the past year or two. The American Society for Testing Materials now has a specification for the electroplating of die castings under consideration, and when this is publicized even further improvement is to be expected. The producers of synthetic plastic finishes have also improved their products, and there are now available finishes of attractive colors which are remarkably resistant to alkaline and other corrosion as well as to abrasion.

Aluminum die castings have for years been produced on gooseneck machines where pressures are limited to a maximum of about 600 psi. and where the iron gooseneck is prone to contaminate the alloy. With good practice and accurate temperature control, aluminum alloys would pick up about 0.3% iron each time they were melted. Due to the proportion of gate and sprue and to rejected castings it is often necessary to melt three pounds for every pound shipped, which would make a total iron pickup of almost 1%. However, with the newer "cold chamber machines" the metal is not in contact with iron except momentarily as it is cast, and the iron pickup is nil. Higher pressures can also be used, and many castings are now produced at operating pressures of several thousand pounds per square inch. In principle these machines are identical with those used for the injection molding of thermoplastics; in the latter, however, the pressures are commonly much higher and the temperatures much lower. Cold chamber machines are so far superior to the gooseneck machine for most castings that new machine equipment is now usually of the cold chamber type.

Both magnesium alloys and copper base alloys are best cast in the same variety of cold chamber machine. Its original development was for the casting of the yellow brasses and other copper base alloys, and its adaptation to aluminum, magnesium and thermoplastics was natural. The tail is now wagging the dog, however, as the current production of cellulose acetate and other thermoplastics is, on a volume basis, greatly in excess of that of any of the metals, and the cold chamber casting of aluminum is in greater volume than that of magnesium and brass. With the present demand for aircraft, die casting of a very considerable amount of the magnesium base alloys is under way. The magnesium alloys suitable for this purpose are about one third lighter than the aluminum alloys, and in the die cast form their mechanical properties are of the same order; where weight is all-important, therefore, the magnesium alloys find extensive use.

Regardless of materials, the commercial die casters today are producing castings with thinner walls, closer tolerances, and superior finishes than would have been thought possible a few years ago. The stricter demands of customers' engineering departments have kept the producers on their toes, and the outcome has been measurable improvements in quality and a wider use of this economical method of producing quantities of interchangeable parts.

MAGNESIUM ALLOYS

Compositions, Properties, and Designations of American Commercial Alloys

Compiled by H. S. Jerabek, University of Minnesota, with the help of W. H. Gross of Dow Chemical Co., and R. T. Wood of American Magnesium Corp.

Form	A.S.T.M. Alloy No.	A.S.T.M. Specification No.	Navy Bureau of Aeronautics Alloy No.	Navy Bureau of Aeronautics Specification No.	U.S. Army Air Corps Grade	U.S. Army Air Corps Specification No.	S.A.E. No.	AMS(j)	Am. Mg. Corp.	Dow Chem. Co.	Composition, Per Cent Magnesium=Remainder Al	Mn	Zn	Condition	Tensile Strength (a) Typical	Tensile Strength (a) Min.	Yield Strength (a) Typical	Yield Strength (a) Min.	Elongation in 2 In., % Typical	Elongation in 2 In., % Min.	Brinell Hardness	Shear Strength (a)	Endurance (b)	Uses and Characteristics
Sand Castings	4	B80-40T	4	M-112g		57-74-1C	50	4420	265	H	6.0	0.2	3.0	As Cast	27	24	11	10	5	4	51	17	10	General casting use.
														Cast; Soln. T. (c)	37	30	12	10	10	6	53	18	10	Sand and permanent mold castings.
									241		8.0	0.1		Cast; Soln. T.; Aged (d)	37	32	18	16	4	2	70	19	9	
	17	B80-40T	17	M-112g			500		260	C	9.0	0.1	2.0	Cast; Soln. T	33	29	11	9	10	6	48	18	7.5	Sand and permanent mold castings.
														As Cast	23	20	14	10	1		62	18	10	Pressure tight castings.
														Cast; Soln. T. (c)	39	30	14	10	10	6	61	20	10	
	2	B80-40T							240	G	10.0	0.1		Cast; Soln. T.; Aged (d)	38	32	20	18	3	1	77	22	10	
														As Cast	21	18	12	10	2	1	53	18	8	Sand and permanent mold castings.
														Cast; Soln. T.; (c)	33	29	12	10	8	5	52	20	10	
	3	B80-40T							246	B	12.0	0.1		Cast; Soln. T.; Aged (d)	34	29	19	17	1		69	22	8	
	11	B80-40T	11	M-112g	2	57-74-1C			403	M		1.5		-"- -"- -"-	32	27	20	17	0.5		85	19	7	Hard castings. Pistons.
Die Castings	12	B94-39T		M-369	1	11319			244		4.0	0.3		As Cast	14	12	4		5	3	33	11		Best salt water resistance.
														-"- -"-	24	20	9	8	6	4	44	14		Aircraft tank fittings.
	13	B94-39T		M-369	1	11319	501	4490	230	K	10.0	0.1	(f)	As Cast	30		22		1		68			Thin section die castings.
									263	R	9.0	0.2	0.6	-"- -"-	33		20		3		66			General die castings.
Extruded Bars and Rods	6	B107-40T							53s	F	4.0	0.3		As Extruded	40	37	29	25	16	12	47		14	General extrusions.
	8	B107-40T	8	M-314c(e)	1	11320(e)		4350	57s	J	6.5	0.2	0.7	-"- -"- (g)	43	40	30	26	17	12	54		17	Improved strength.
	8	B107-40T	8	M-314c(e)	1	11320(e)	520		57s	J	6.5	0.2	0.7	-"- -"- ; Stretched (g)	44	40	32	26	15	12	55	20	15	Screw machine rod.
	11	B107-40T	11	M-314c	2	11320			3s	M		1.5		-"- -"-	42	32	27	20	6	5	42		10	Best salt water resistance.
	9	B107-40T							58s	O	8.5	0.2	0.5	-"- -"-	47	43	33	28	11	9	61		17	Bars of high strength.
	15	B107-40T	15	M-314c(e)	1	11320(e)	521		24s	X	3.0	0.2	3.0	-"- -"-	42	39	30	26	19	15	51		18	Heat treatable bar.
	15a	B107-40T	15a	M-314c(e)	1	11320(e)	521		24s	X				-"- -"- ; Aged	44	41	34	30	13	10	54		17	
									59s	G	10.0	0.1		-"- -"- ; Stretched	51	45	38	33	9	6	70	23	16	Highest hardness and strength.
	18	B107-40T					52		52s	Fs	2.8	0.3	1.0	-"- -"- -"-	40	37	30	25	17	12	50	19	12	Good ductility and impact toughness.
Extruded Structural Shapes	8	B107-40T	8	M-314c(e)	1	11320(e)	520		57s	J	6.5	0.2	0.7	As Extruded	42	38	27	23	15	10	58			Good strength and weldability.
					2	11320			3s	M		1.5		-"- -"-	35	30	23	16	6	3	42			Best salt water resistance.
	15	B107-40T	15	M-314c(e)	1	11320(e)	521		24s	X	3.0	0.2	3.0	-"- -"-	42	39	25	22	17	10	59			Heat treatable shapes.
	15a	B107-40T	15a	M-314c(e)	1	11320(e)	521		24s	X				-"- -"- ; Aged	43	40	28	25	14	8	62			
									58s	O	8.5	0.2	0.7	As Extruded	44	40	29	25	11	8	58			Improved strength.
	18	B107-40T							59s	G	10.0	0.1		-"- -"-	48	45	37	30	9	6				Highest hardness and strength.
							52		52s	Fs	2.8	0.3	1.0	-"- -"-	39	35	28	22	15	11				Good ductility and impact toughness.
Extruded Tubing			8	M-366b(e)	1	11318(e)	520		57s	J	6.5	0.2	0.7	As Extruded	40	36	19	17	9	7	55			Good strength and weldability.
			11	M-366b	2	11318			3s	M		1.5		-"- -"-	35	32	17	17	5	3	40			Best salt water resistance.
			15	M-366b(e)	1	11318(e)	521		24s	X	3.0	0.2	3.0	-"- -"-	40	36	19	17	9	7	55			Heat treatable tubing.
							521		24s	X				-"- -"- ; Aged	41	37	22	19	7	6	59			
									58s	O	8.5	0.2	0.7	-"- -"- -"-	42	39	29	25	5	4	60			Highest strength tubing.
							52		52s	Fs	2.8	0.3	1.0	As Extruded	35	32	16		11		50			Good ductility.
Press Forgings	8	B91-40T	8	M-126d(e)				4350	57s	J	6.5	0.2	0.7	As Forged	41	38	25	22	9	6	56	21	15	General forging. Good ductility.
			11	M-126d					3s	M		1.5		-"- -"-	33	29	19	12	6	2	43			Weldable forgings.
	9	B91-40T	9	M-126d(e)		11321(e)		4360	58s	O	8.5	0.2	0.5	-"- -"-	45	42	30	24	7	5	69	22	16	Forgings, simple design. Strong.
	15	B91-40T	15	M-126d(e)					24s	X	3.0	0.2	3.0	-"- -"-	41	38	24	20	16	9	59		17	Heat treatable forgings.
	15a	B91-40T	15a	M-126d(e)					24s	X				-"- -"- ; Aged	42	38	28	22	14	7	62		17	
Hammer Forgings	16	B91-40T							65s		3.5	0.2	(h)	As Hammer Forged	38	35	22	20	12	6	52	16	10.5	Hammer forgings.
										L	3.0	0.2	(i)	-"- -"- -"-	37	34	26	19	11	6	51		10.5	-"- -"-
Rolled Plate, Sheet & Strip	7	B90-40T					511			Eh	6.5	0.2		As Hard Rolled	45	39	34	28	9	3	70			Sheet with high strength.
										Ea				Annealed	39	(42 max.)	20		15	10	57			
	6	B90-40T					510		53s-H	Fh	4.0	0.3		As Hard Rolled	44	36	35	25	10	4	60			Sheet with high strength.
									53s-O	Fa				Annealed	36	(38 max.)	22		18	10	50	18	10	
	11	B90-40T	11	M-111e	1	11317-A	51	4370	3s-H	Mh		1.5		As Hard Rolled	37	32	27	24	9	4	53			Sheet with best formability and salt water resistance.
									3s-O	Ma				Annealed	32	(35 max.)	16		15	12	44	17	8	

(a) In 1000 psi. Yield strength is the stress at which the stress-strain curve deviates 0.2 % from the modulus line.
(b) Endurance or fatigue limit for 500 million reversals of the load, in 1000 psi.
(c) Solution heat treatment: Soaking at about 630 to 810 °F. followed by air quenching.
(d) Solution treatment followed by artificial aging at about 350 °F. (precipitation hardening).
(e) Compositions with 0.005 % Fe max. and 0.005 % Ni max., for improved resistance to salt water are required by these specifications. (Dowmetal J-1, O-1, X-1, and AMC 57s).
(f) Contains 0.5 % silicon.
(g) Extruded and stretched is the condition in which bar and rod is normally furnished.
(h) Contains 5.0 % tin.
(i) Contains 3.5 % cadmium.
(j) Aeronautical material specification, Society of Automotive Engineers, Inc.

Aluminum and Its Alloys

By T. W. Bossert
Asst. Chief Metallurgist, Fabricating Division
Aluminum Co. of America

IN ANTICIPATION of the growing demand of American industry for aluminum and aluminum alloys, appropriations totaling more than $50,000,000 have been made since 1937, by producers in this country, for the expansion of plants and facilities for the production and fabrication of aluminum and its alloys. Outstanding in the past year has been the construction of a new metal producing plant at Vancouver, Wash., which will use electric power supplied by the U. S. Government's Bonneville power project on the Columbia River. Several additional power dams are now under construction in the region of the Great Smoky Mountains to furnish electric power for additional production of aluminum in the southeastern states.

Facilities for the manufacture of fabricated products of aluminum and aluminum alloys such as sheet, tubing and extruded shapes, have been further expanded by additions to present plants, and by construction of new plants — as, for example, the new extrusion plant in the Los Angeles area.

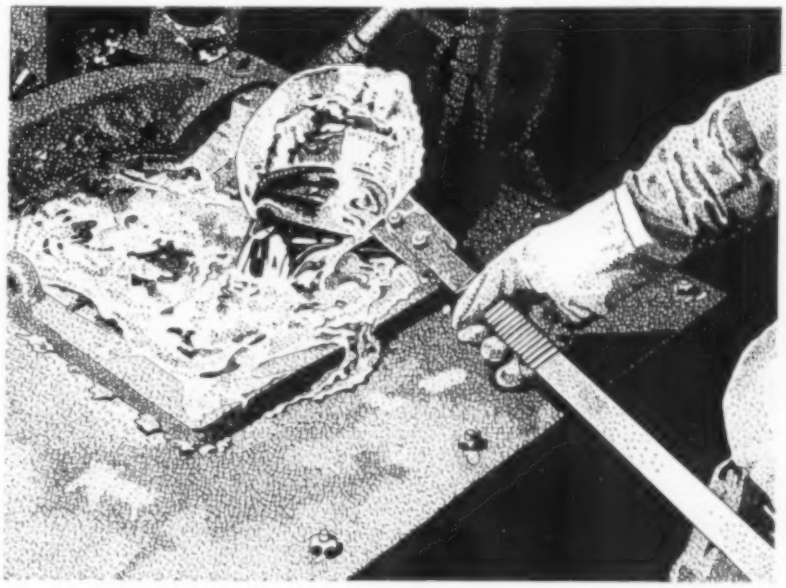
The timeliness of the entire expansion program with respect to the present world situation has placed the industry in good position to meet the growing demands of the national defense program.

A survey of trends in the aluminum industry over the past two decades reveals the fact that the preponderant tonnage of metal today goes into engineering applications requiring the use of alloys heat treated to produce high strength, whereas in the early 1920's most of the metal was used for applications requiring low or medium strength. Important factors in this change have, of course, been the development of new alloys by research, and the realization, by users, of the tremendous advantages of the light weight of this metal, combined with uniform strength and reliability.

During 1940, two reductions in the price of ingot aluminum, each for 1¢ per lb., were announced. These reductions have decreased the price of aluminum ingot 10%, and are particularly significant in view of the fact that they were made in a period of rising demand and rising labor costs.

Development of a new high strength alloy for aircraft propellers was completed in 1939. The advantages resulting from the use of this alloy in propellers are of particular importance to transport planes, large flying boats and to aircraft for the national defense program.

Installation of the world's most powerful testing machine, in the Aluminum Research Laboratories at New Kensington, Pa., was completed early this year. This machine is capable of exerting a force of 3,000,000 lb. in compression, or 1,000,000 lb. in tension, at a head speed of 36 in. per min. It will be used primarily for research in metal working by extrusion, forging, pressing and drawing, but it is also intended for employment as a universal testing machine for large shapes and fabricated assemblages.



Magnesium and Its Alloys

By L. B. Grant
Dowmetal Sales Manager, Dow Chemical Co.

METALLURGISTS and metal men of the future will undoubtedly look back at 1940 as the year that magnesium took its real place as a structural metal in the industrial and manufacturing life of this country. Almost over night it has come to the front as an extremely necessary and useful material of construction where lightness is needed.

To meet this rapid increase in demand, production of magnesium was doubled early in

(c) Aeronautical material specification, Society of Automotive Engineers, Inc.

Properties of Commercial Copper

From "The Commercially Important Wrought Copper Alloys," by Chase Brass & Copper Co.

Chemical and Physical Properties

Name	Composition	Density; Lb. per Cu. In.	Melting Point; °F.	Coefficient of Thermal Expansion; Average 25° C. to 300° C.	Electrical Conductivity; % I.A.C.S. (Annealed)	Thermal Conductivity Cal./Sq. Cm./Cm./Sec./°C. at 20° C.
Electrolytic tough pitch copper	Oxygen about 0.04%	0.323	1980	17.7×10^{-6}	101%	0.94
Oxygen-free copper	Substantially pure copper	0.323	1980	17.7×10^{-6}	101%	0.94
High conductivity phosphorized copper	Phosphorus about 0.007%	0.323	1980	17.7×10^{-6}	101%	0.94
Low conductivity phosphorized copper	Phosphorus about 0.02%	0.323	1980	17.7×10^{-6}	80 to 90%	0.77 to 0.85
Arsenical copper	Arsenic about 0.25%	0.323	1980	17.7×10^{-6}	45 to 80%	0.46 to 0.73
Tellurium copper						
Type A	Tellurium about 0.5%	0.323	1980	18×10^{-6}	98%	0.92
Type B (hardened)	Tellurium 0.5%, nickel 1.0%, phosphorus 0.2%	0.323	1900	18×10^{-6}	60%	0.62

Fabrication Properties

Name	Approximate Relative Suitability for Being Worked		Best Temperature for Hot Working; °F.	Approximate Relative Suitability for Being Welded				Approximate Relative Machinability	
	Cold	Hot		Gas	Carbon Arc	Metal Arc	Resistance	Rating*	Type Chip
Electrolytic tough pitch copper	Excellent	Excellent	1400-1600	Poor	Fair	Good	Poor	20	Long
Oxygen-free copper	Excellent	Excellent	1400-1600	Fair	Good	Good	Poor	20	Long
High conductivity phosphorized copper	Excellent	Excellent	1400-1600	Fair	Good	Good	Poor	20	Long
Low conductivity phosphorized copper	Excellent	Excellent	1400-1600	Fair	Good	Good	Poor	20	Long
Arsenical copper	Excellent	Excellent	1400-1600	Fair	Good	Good	Fair	20	Long
Tellurium copper									
Type A	Excellent	Excellent	1400-1600	Fair	Fair	Fair	Poor	100	Short
Type B	Excellent	Excellent	1400-1600	Fair	Fair	Fair	Fair	100	Short

*Free cutting brass = 100.

Average Hardness and Tensile Properties of the Seven Types of Copper

Figures are average and not to be used for specification purposes.

Section Grain Size or Temper Heat Treatment	Rockwell Hardness		Tensile Strength; Psi.	Yield Strength at ½% Elongation Under Stress; Psi.	Elongation in 2 In.; %	Shear Strength; Psi.
	F	B				
0.040-in. sheet; 0.015 mm.; anneal	45	..	35,000	10,000	40	24,000
0.040-in. sheet; 0.030 mm.; anneal	40	..	32,000	10,000	45	23,000
0.040-in. sheet; hard	90	..	51,000	45,000	10	28,000
0.040-in. sheet; spring	95	..	57,000	53,000	6	29,000
1 x 0.049-in. tube; 0.030 mm.; anneal	40	..	32,000	10,000	45	23,000
1 x 0.049-in. tube; hard	90	..	50,000	45,000	12	28,000
No. 12 B.&S. wire (0.081 in.); 0.030 mm.; anneal	..	..	32,000	10,000	..	24,000
No. 12 B.&S. wire; hard	..	..	60,000	55,000	..	30,000
1-in. rod; hard	..	..	40,000	.....	30	25,000
1-in. rod; hard (Type B tellurium copper only)	..	76	70,000	47,000	18	45,000

1940 and will again be doubled by January, 1941, thus giving the United States a total production capacity of approximately 25,000,000 lb. of magnesium metal per year.

This demand has been accelerated by the great increase in aircraft building, but it is significant that the increased volume of magnesium has come about more by the greater use of magnesium per plane than by the greater number of airplanes built. Other industries have been quick to follow this lead in the wider use of magnesium, particularly in the manufacture of business machines, textile machinery, and transportation.

These larger uses have added great impetus to research and development, particularly along the lines of better alloys and improved fabrication processes. It has also brought many more fabricators of magnesium alloys into the field; it is estimated that approximately 20 companies are now producing magnesium alloy sand castings or die castings. The greatest volume of magnesium alloys continue to be sold in the form of sand castings, but die casting is a close second. Magnesium alloy extrusions and sheet are also of great interest, and we predict that in the very near future magnesium alloys in these two forms will be used in large quantities in aircraft for the construction of such vital parts as fuselages and wings. The use of magnesium alloy forgings is just beginning to receive attention and much progress may be expected as this field is explored.

The Copper Industry

—Casting Problems—Oxygen-Free Copper—Electro-Formed Sheet

EDITOR'S Note—Three very friendly and competent but also very busy men, metallurgists for three of the large copper and brass companies, were asked in succession to write something about interesting things happening in their industry, but each begged off. Rather than leave the impression that things are stagnating, THE EDITOR appends three "Critical Points", written months ago, about things which to him at least were stimulating.

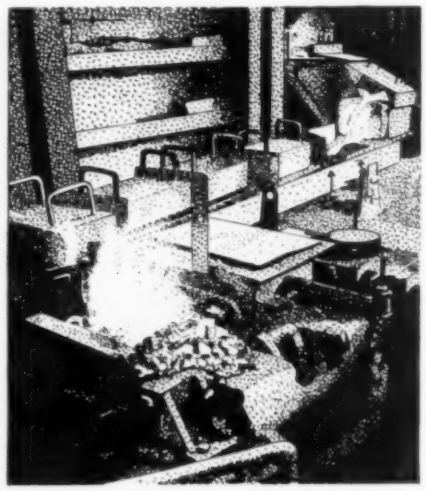
AFTER inspecting the machinery at International Smelting & Refining Co. in Perth Amboy, N. J., was convinced that a page in the March (anniversary) issue might properly have been devoted to copper billets, as they were cast in 1915 and as they are cast in 1940. Pre-war recollections are of an endless chain of workmen, each carrying a hand ladle of copper from furnace to mold. Or, if the molds were set on a merry-go-round or "wheel", they were merely open-topped depressions in heavy metal slabs, filled by a stream from the furnace. The copper itself was carefully "poled" so the correct amount of gas would separate in a multitude of tiny cavities during solidification to compensate for the natural shrinkage and form billets, bars or slabs of crinkly but relatively flat upper surface. Such "tough pitch copper" corresponds to "rimming steel" in soundness and economic justification . . . .

automatic casting of gas-free copper

VERNON MACDONELL, mechanical superintendent of the Raritan Copper Works, showed me the 1940 way. Water-cooled molds for round billets in pairs, of welded steel, are set vertically around the circumference of a casting wheel and closed at the bottom with a hinged copper slab. Prior to casting each mold is blown out, polished with motor driven brushes, swabbed with oil, and a double-spouted basin set on top. Refined copper flows continually into a tilting pouring ladle and two of the double molds are poured simultaneously during a single pause of the casting wheel. After each tilt a measured amount of phosphorus is put into the pouring basin to deoxidize the metal coming into it for the next pour. The metal then is "killed" with a slight excess of phosphorus; it evolves no gas on solidifying, but it does pipe. This pipe is minimized only by a slow pouring rate—hence the plan of pouring four billets simultaneously. Its superior physical properties over the tough pitch copper have made it the standard metal for tubing, and these round billets must have a surface so good as to require no scalping; the piped end merely is cut off before going to the piercers. MACDONELL said the same equipment is used for the vertical casting of wire bars. Large rectangular slabs so cast are cut in odd-sized cakes, to order; sheet and plate rolled from deoxidized copper are free from segregated cuprous oxide eutectic, which sometimes splotches the finished surface of products rolled from tough pitch copper cast in open-top cakes.

DISCUSSED with STANISLAUS SKOWRONSKI, research engineer at the Raritan refinery, the problem of purity and conductivity of copper. He emphasized the fact that it was purity of the copper crystal (or the solid solution called "copper" by the metallographer) that is

responsible for high conductivity. Cathode crystals, from the refining tanks, are regularly 99.99% copper, and have a conductivity of 102 to 102.4% of the international standard. These cathode crystals are usually melted and cast into billets, bars or slabs, but what with the growth of powder metallurgy they can be deposited or broken fairly fine, washed free of electrolyte, pressed into slugs, sintered in a reducing and desulphurizing atmosphere, extruded into rod and drawn into wire. In fact, this is now being done commercially by the Phelps Dodge Copper Products Corp., and the product is exploited as a really oxygen-free, high purity, high conductivity wire, which by virtue of its extrusion and cold drawing is free from surface slivers arising in the rolling mill. . . . . Cathode crystals, melted by flame, acquire much oxygen. As is well known, this is reduced by poling to the correct amount and in the solid copper the remainder exists as a copper, copper oxide eutectic at the grain boundaries, not so large in extent but that the conductivity can still be 101% or more. However, the physical properties are lowered, especially after annealing in a protective atmosphere as is becoming more and more common. Hence the need of "oxygen-free" copper, first offered by United States Metals Refining Co. in 1932, and now sold by the millions of pounds monthly. SIDNEY ROLLE, who has been in charge of technical matters in this connection since the beginning, tells me that cathodes melted in an electric furnace under charcoal acquire no oxygen and can be cast oxygen-free by enclosing the spouts and runners and casting into gas-filled molds. Power rates being what they have been at the refinery in Cartaret, N. J., it has been more economical to melt continuously in a fuel-fired reverberatory furnace, keep the oxygen down by poling, eliminate the last traces by running the hot copper through a box of incandescent charcoal, then hold this deoxidized copper under charcoal producer gas (30% CO, 70% N_2) in a "pour hearth". This last is a cylindrical rocking furnace wherein the copper is heated by induced currents and held within close temperature limits: the pour hearth is tilted to fill the gas-filled molds. . . . . ALBERT PHILLIPS, superintendent of the research department of American Smelting and Refining Co., also tells me his firm makes a third variety of high conductivity, low oxygen copper by transferring carefully refined and poled copper to a ten-ton holding furnace in which it is held under charcoal and there deoxidized with phosphorus. The phosphorus possibly catalyzes the reaction between carbon and copper oxide for less is added than is needed to satisfy the oxygen; a little residual actually remains to protect the copper during casting. It is rather a delicate matter to adjust everything so the wire bars, as-cast, are sound and have a good surface in addition to good conductivity and annealing properties (neither an excess of phosphorus nor any discoverable cuprous oxide).



three kinds of "oxygen-free" copper

VISITED the Raritan Copper Works in Perth Amboy primarily to inspect the department for making thin copper sheet by continuous electrodeposition on a rotating drum. Eight machines make heavier sheet weighing 1 to 2 oz. per sq.ft., 64 in. wide and a half-mile long; six narrower machines are for 30-in. sheet, sometimes so thin as to weigh $\frac{7}{32}$ oz. (Sheet weighing $\frac{1}{8}$ oz. has been made experimentally for electrical condenser leaves. This is about 0.00017 in. thin — it would take five of them to be as thick as toilet tissue.) Electrolyte, already conditioned, is drawn from the main tank room of the copper refinery, and passed rapidly through the machines in series, so the copper content is depleted very little before its return. The continuously polished drums, about 85-in. diameter, are less than half submerged, and pass within $\frac{3}{4}$ in. of accurately conforming anodes of the same insoluble lead-antimony alloy. Within this curved passageway the electrolyte is stirred by air jets, and copper is deposited at a uniform rate, so that the sheet's thickness is quite uniform and easily controlled by the speed of the drum. Electro-formed sheet, still adhering to the drum, is wiped free

electro-formed copper sheet

of electrolyte by a rubber squeegee, then washed by water sprays, then led back away from the drum to a coiler. It lifts off freely. One side of the sheet is smooth, the other side is mossy crystalline — a fact of advantage for it gives the sheet a good "tooth" when cementing to building paper or asphaltic fabric. This is the largest use; 2-oz. sheet (about the thickness of writing paper) so backed up has developed important new outlets for copper in the form of moisture-proof building paper, flashings, and seamless pans under bathroom floors. Rolled sheet cannot serve these purposes because of limitations of width and thickness; likewise the superior physical properties of rolled sheet are not necessary. HARRY MACAN, departmental superintendent, said the success of the operation depended on the ability to prevent the deposition of any copper at the very edge of the drum; when this was uncontrolled the sheet would grow around the end, locking it so it could not be peeled off. Success finally followed the placement of glass partitions close to the ends of the drums so the circulating electrolyte outside could be separated from stagnant electrolyte inside the drum by a rubber rope. Auxiliary electrodes of copper sheet were placed inside close to the glass plate and maintained at a potential enough lower than the drum so that any copper that might deposit at or near the edge would be speedily deplated to this auxiliary anode. . . . . Despite MACAN's statement, this observer would say that success of the whole operation depends on the combined knowledge and experience of the staff and the resources of one of the world's leading refineries.

Beryllium and Beryllium Copper

By Louis L. Stott
Sales Manager, The Beryllium Corp. of Pa.

PRODUCTION of beryllium has followed a steady upward trend, and this element appears destined to become one of the important alloying ingredients in the non-ferrous field. Most of the metal is now produced as a master alloy with copper, containing approximately 4% beryllium. This material, made by thermic reduction of beryllium oxide in the presence of copper, is much more economical to make than by any known process of producing pure beryllium and then re-alloying. Beryllium metal continues to be produced by high temperature electrolysis of beryllium chloride; only relatively small quantities are consumed, largely due to the present price of approximately $45 per lb. The master beryllium-copper alloy is, however, currently sold at $15 per lb. of contained beryllium, with the copper content at market.

Wrought beryllium-copper alloys now range in beryllium contents from 0.1% to approximately 2¼%; the best known and the one longest on the market contains approximately 2 to 2¼%. Although this was originally supplied as a binary alloy, it has been found that important advantages follow the addition of other metals. For example, 0.25% cobalt has improved the uniformity of properties, and the ease of precipitation hardening, as well as permitting the beryllium content to be reduced to 1.8% without loss of the properties obtainable by heat treatment. Since this 1.8% alloy can be more readily homogenized during production anneals, and thereby stand heavier cold reductions, it seems probable that this slightly lower alloy may supplant the older alloy. Another beryllium-copper alloy which has appeared on the market contains approximately 0.5% beryllium, 2.6% cobalt, and balance copper. Still another is of the chromium-copper type, containing approximately 0.1% beryllium, 0.3% chromium, balance copper. These latter two materials are primarily high conductivity alloys (conductivity approximately 50% and 70% that of copper, respectively) with excellent strength and hardness.

Springs comprise the principal use for beryllium-copper alloys in strip and wire form. They have certain unique and useful purposes, for both flat and helical springs where stability of spring pressure or constant deflection is required, such as in aviation instruments and control instruments of all kinds, where springs must be calibrated to extreme accuracy. It has been suggested that the very low "elastic drift" results from the circumstance that the temperature for relief of stresses is about the same as that required for precipitation hardening.

The capacity of beryllium-copper alloys to be heat treated after being severely cold worked

in a relatively soft temper has opened up interesting possibilities in design. In the automotive field, for example, small solderless connectors are used in the lighting system, wherein a one-piece spring clamp is formed and heat treated from strip in such a way that a vibration resistant joint is made without the necessity of soldering. Another interesting advantage is the ability to silver solder beryllium copper and subsequently heat treat it to obtain high spring properties. A number of temperature control devices of the capsule type for the refrigerator and automotive field, made from silver soldered beryllium-copper diaphragms, have recently appeared.

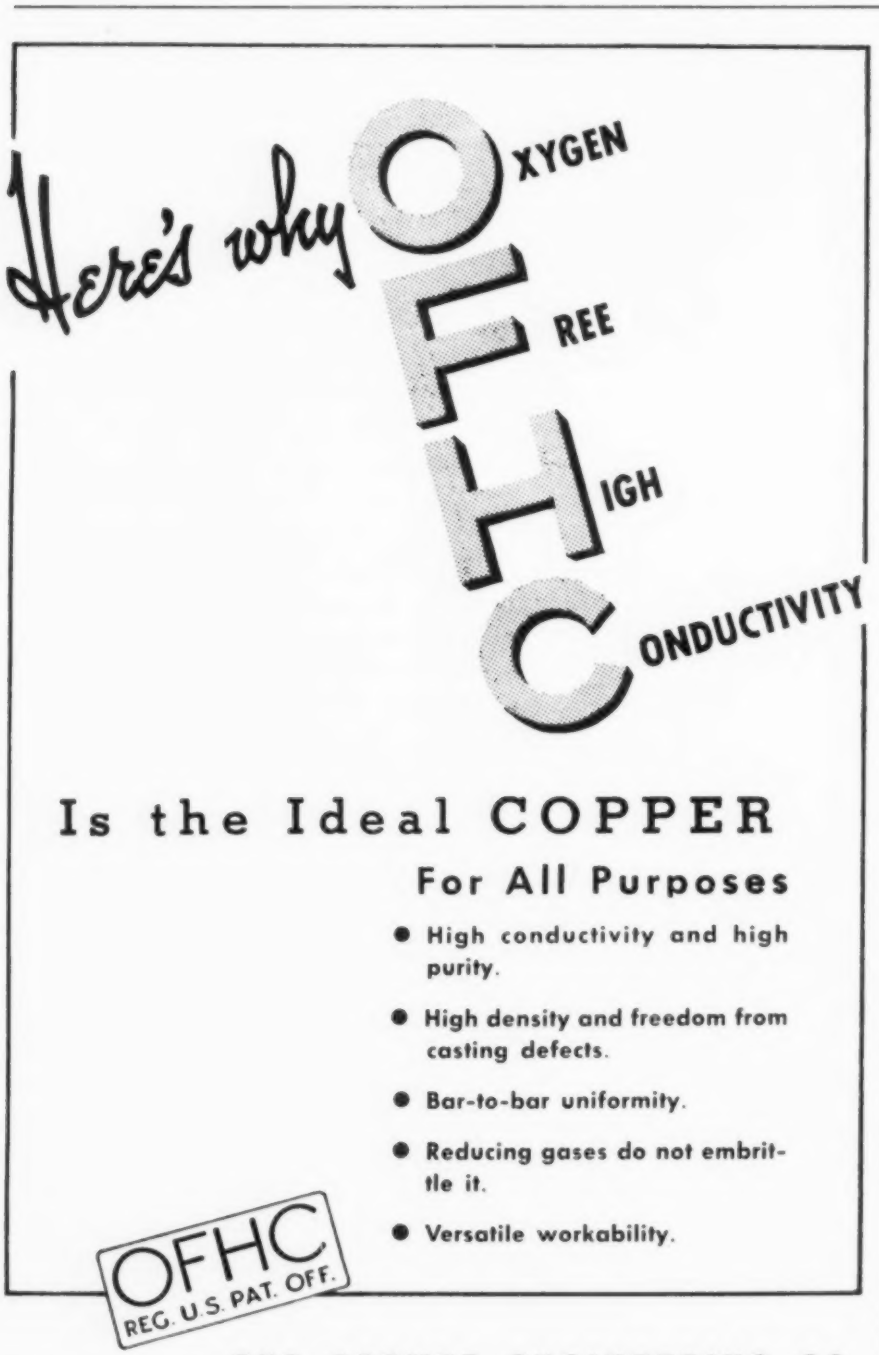
One of the prominent aviation engine builders reports that 2% beryllium copper is used for tappet roller bearings and counterweight bushings. In the former case extremely high bearing pressures, estimated at between 15,000 and 20,000 psi. are being successfully withstood.

Beryllium-copper castings have lagged behind. Early experiments had indicated non-uniform hardenability, and a tendency to crack during the quench. Additions of 0.5 to 1% of metals of the iron group have corrected these unsatisfactory qualities. Small silicon additions to such alloys have also proved beneficial. One very interesting sand casting alloy contains approximately 1.75% beryllium, 0.5% cobalt, 0.3% silicon, balance copper, and can be heat treated to a range of properties between 117,000 psi. ultimate with 10% elongation in 2 in., to 150,000 psi. and 3% elongation.

Beryllium-copper alloys have been cast in molds of plaster of paris and asbestos, anticipating that some intricately shaped steel parts expensive to machine could be replaced economically by casting beryllium copper to close dimensions and then heat treating. Small parts cast from an alloy containing 2.75% beryllium, 0.5% cobalt, and balance copper, have been heat treated to hardnesses on the order of Rockwell C-47, and have shown very favorable wear resisting characteristics in comparison with the steel parts substituted.

Sand castings of the alloy 0.5% beryllium, 2.6% cobalt, balance copper, are attractive to the electrical industry because of a combination of yield point and electrical conductivity. A heat treated sand casting of this analysis will show a 0.2% yield point of approximately 80,000 psi. and conductivity between 45 and 50%. Jaws of outdoor disconnect switches can be cast from it, relying on the spring properties of the casting to supply the necessary contact pressure, thus eliminating steel backing-up springs.

In view of the Army and Navy interest in high quality materials, beryllium copper is being specified for a growing number of military purposes. It seems probable that the defense program should give a considerable impetus to its use.



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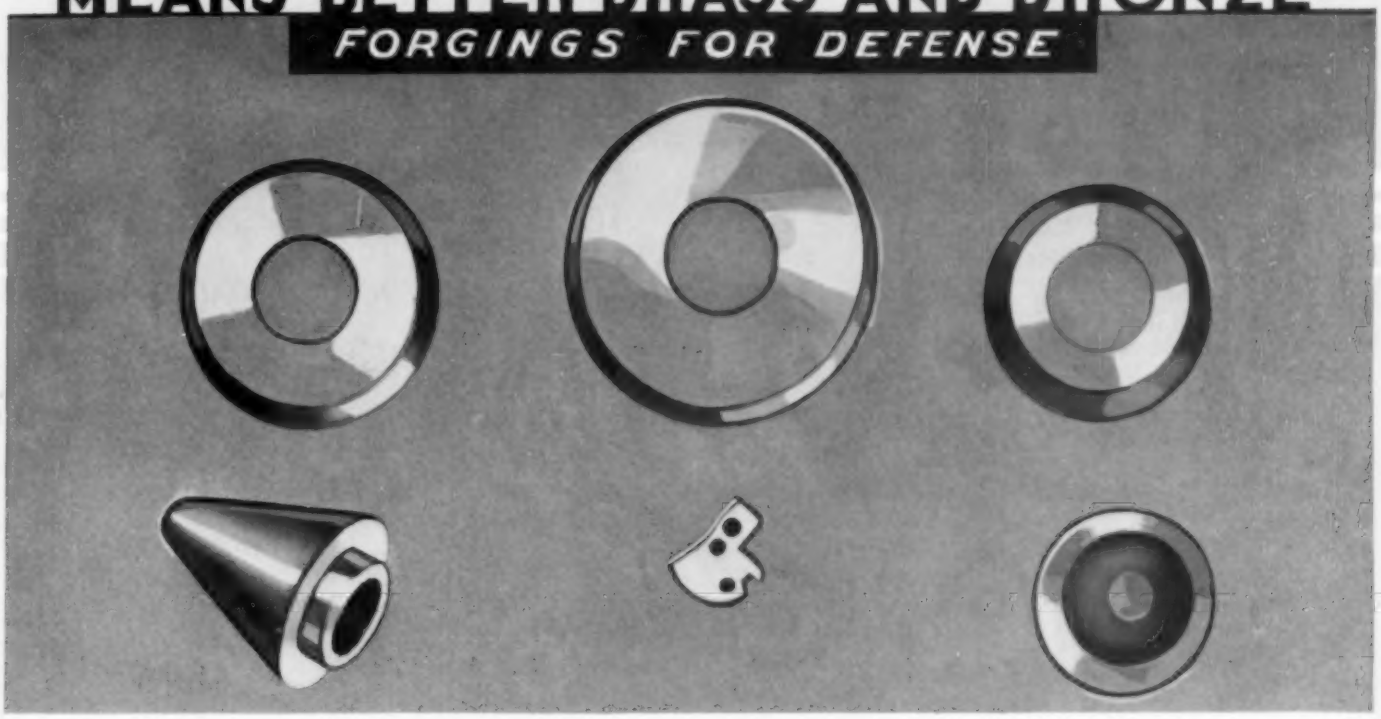

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HIGH TEMPERATURE APPLICATIONS analyzed and pictured in a recently printed Bulletin, C-8. For latest facts on "High Temperature Uses of Monel, Nickel and Inconel", please mail your request to the address below.

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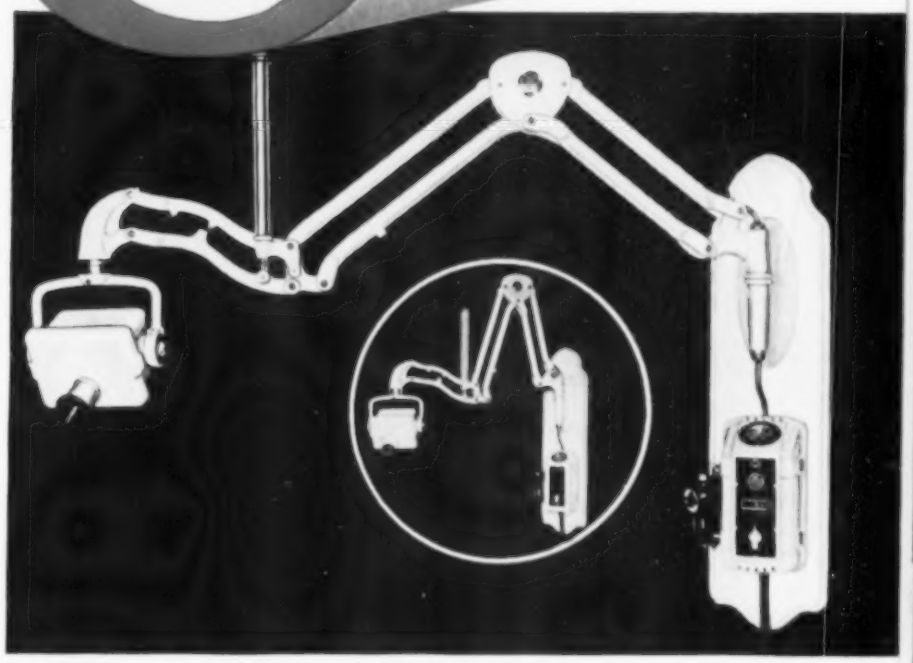

The flexible extension arms of this Fisher Dental X-Ray Apparatus are made of DOWMETAL Sand Castings by Hills-McCanna Co. They eliminate weight and assure ease of adjustment.

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Alcoa Aluminum die castings (13 on this contactor) have proved their dependability on many moving and fixed parts in contactors built by The Electric Controller & Mfg. Co. of Cleveland.

No delicate materials can be used here. If you've ever listened to electrical contactors slamming shut, you know the repeated shocks and beatings their parts must take.

On EC&M magnetic contactors, moving parts are Alcoa die castings made of strong Aluminum Alloys. These die castings not only have adequate strength, endurance and electrical conductivity, but their light weight provides the low moment of inertia that is so important for lightning responses to demands of modern, quick-operating machinery.

Steel inserts are cast integrally with the Aluminum for contactor arms that must respond to magnetic pull. Threaded brass inserts are included in the same way. So accurate are these die castings, that very little finishing is required.

Aluminum Company of America, 2101 Gulf Building, Pittsburgh, Pennsylvania.

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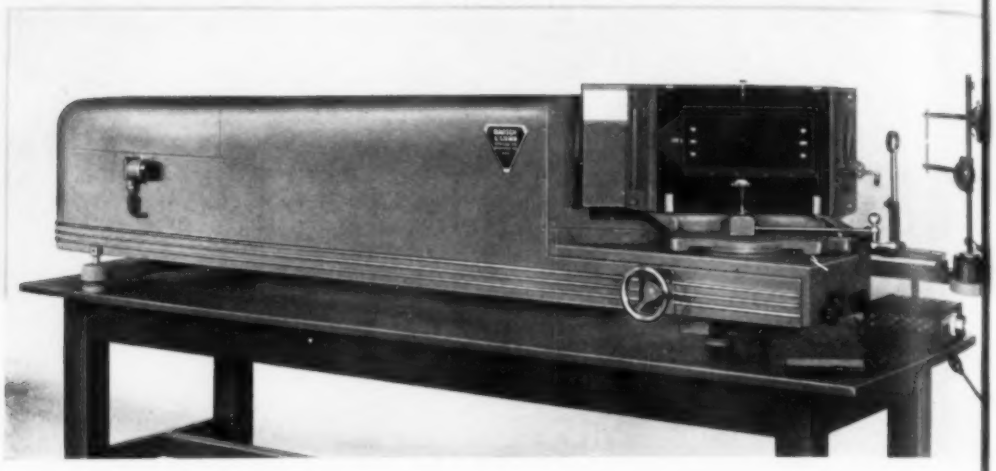

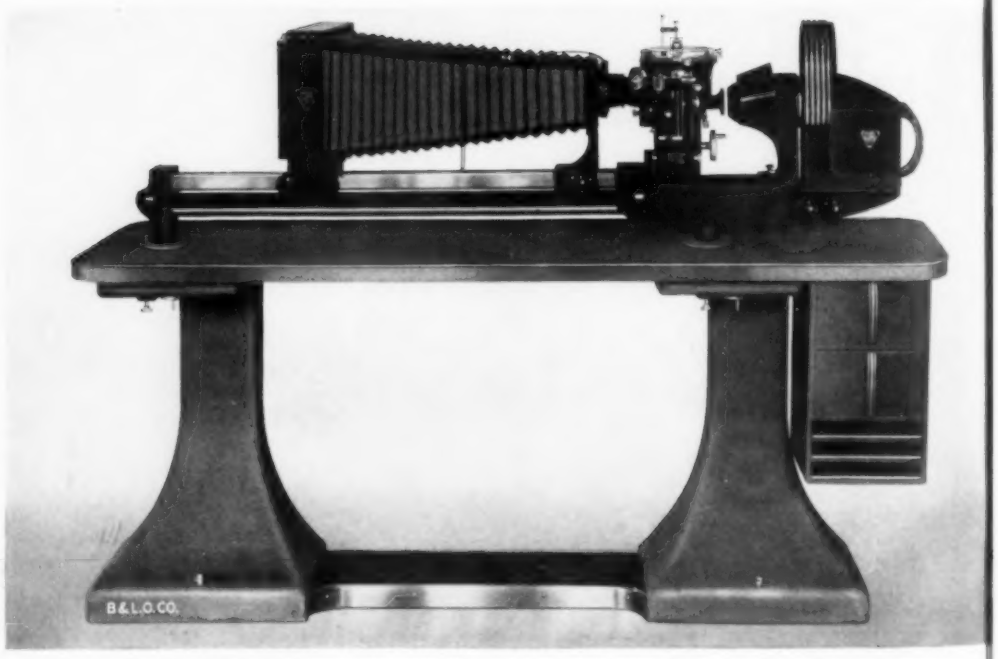

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Instruments

Pyrometry
Especially of Molten Steel

THE LOGICAL SOURCES of information for this section were so expertly milked by the Temperature Symposium of less than a year ago (reported by JOHN S. MARSH in last December's issue) that the EDITOR is now forced to use a few notes compiled by a mere onlooker. This obviously precludes startling disclosures. However, accomplishments of pyrometrists working in the difficult range of steel-making temperatures have not been publicized to their warrantable extent, and those able to tell all have shown some reluctance to do so — for reasons that include the fact that perfection has hardly been achieved. Consequently, a few hints on what they are doing may be of interest.

Many openhearth furnaces are now equipped with devices for measurement and control of temperature and combustion, but there is no agreement yet among operators on the best way of measuring bath temperatures. The ubiquitous optical pyrometer has been pronounced not invariably good for the purpose, and several alternate tests have been devised, but all are wanting in one respect or another.

For example, in the "spoon test" a sample of steel is dipped into a well-slagged spoon, then poured out slowly. The amount of frozen residue is supposed to indicate the bath temperature, but the indication is necessarily crude. A reliable practical method in competent hands is known as the "rod test". In this, a steel rod is immersed and moved about slowly; by due consideration of immersion time and slag viscosity, as well as the form of the "cut" end of the rod, the operator deduces the bath temperature. If steel builds up on the rod, the bath is "very cold"; if the rod melts off to a long point, it is "cold"; if the cut is square, it is "hot", and if the cut is square or concave and if there are nicks in the slag region, the bath is "very hot". These degrees of thermal intensity doubtless seem very imprecise to what may be called the Type *K* virtuoso, but they are adequate in their way.

In the "rod-boil test" an optical pyrometer is sighted on metal exposed by the boiling action of an immersed steel rod. The principal trouble here is that the boil is not violent enough to expose metal through openhearth slags of desirable viscosity.

Thermocouples have not been neglected, of course; the FITTERER graphite *vs.* silicon carbide junction has been praised and damned. Precious-metal couples have been adapted to the rigors of steel-making service in England, and high-melting metals such as tungsten and molybdenum have been proposed, although the response to date is less than overwhelming. Still another method — and one eliciting considerable interest and argument among steelmen — is that of the COLLINS-OSELAND tube in which a steel tube having a glass window at one end is inserted into the bath; air blown through the tube maintains a clean surface on the steel, which is used for sighting by means of an optical pyrometer. Apparent emissivity is altered by the process, and special calibration is necessary. Recent experiences indicate that this is not an insuperable difficulty, and it is said that even melting crews will take the outfit seriously.

Before leaving these variegated tests of steel-bath temperature, a device noteworthy for its lack of personal equation, otherwise known as the "equalization method" of LARSEN and SHENK, should be mentioned. A roof-control (photo-electric) pyrometer is sighted on the openhearth roof and another of the same type is aimed at the slag. When the flame is shut off during the late stage of the heat, the temperature is equalized rapidly by radiation, and roof, slag, and steel come to thermal equilibrium; this is indicated by null readings of the two pyrometers connected in opposition.

This does not complete the list of techniques in use, but those described are sufficiently indicative of what the steel-plant pyrometrist has to cope with. If there is a trend to be noted,

it is probably in the direction of instruments making use of photo-electric tubes. In this connection, it may be mentioned that a two-color optical pyrometer was described recently, based on the supposition that the ratio of intensities of two radiations of different wave length provides a direct measure of temperature. The instrument itself contains an inclined semi-transparent gold mirror which transmits green light and reflects red light; these components are collected by photo tubes, then amplified for intensity-ratio measurement. How many problems this device will solve remains to be seen.

In other fields of temperature measurement things seem to be about as they were a year ago. Air temperature is still pretty determinable from number of cricket chirps per minute, or from the rate of egress of bees from the hive; computed stellar temperatures continue to range high in the thousands; and clinical thermometers go on despite the invention of sulfanilamide and its derivatives.

In conclusion, it is clear that the good old days are gone forever, when a thermocouple connected to a simple millivoltmeter gave all the information thought possible or necessary. The modern experimental pyrometrist not only dissects his temperature problems with complicated mathematical apparatus but also makes use of equally complicated electron tubes and electrical networks in their determination and control. The existence of temperature is exceedingly important to industry, and pyrometrists are doing their best to keep it under control.

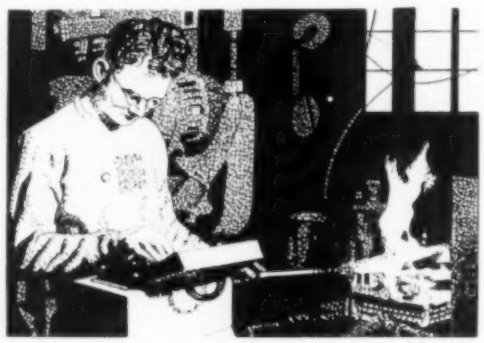
Machinery for Mechanical Testing

By Francis G. Tatnall
Testing Machine Dept.
Baldwin Southwark Div. of the Baldwin Locomotive Works

FATIGUE TESTING has been in the forefront during the past year. In fatigue testing the important things are accurate control of frequency and amplitude; it must also be possible to shift the stress range so that the operation may be from maximum tension to maximum compression in each cycle along a sine curve, or from zero to anywhere in the tension range or anywhere in the compression range in each cycle. Further, it must be possible to apply a dead load and superimpose a sine form of live load upon it.

There are three outstanding methods of doing this. First is the electro-dynamic or induced vibration (at or near resonance) by electro-magnets with a special amplitude control such as the Rayflex method. Second is mechanically induced vibration, at or near resonance, by a pair of eccentric weights revolving in opposite directions, such as in the Bernhard mechanical oscillator. Finally is the forced vibration method by means of motor-driven eccentrics providing *(a)* repeated tension-compression as the Templin fatigue machine, or *(b)* repeated torsion as the H. F. Moore machine. Either of these provides easy adjustment in various regions above or below the zero line.

The small size Templin machines (tension-compression) are popular with aircraft engine manufacturers. The large size machines have been doing important work on structures and

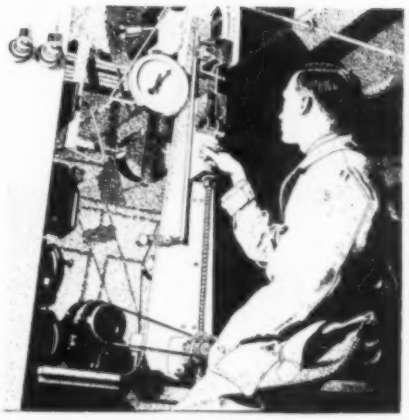


large joints, notably by Wilson at the University of Illinois, and by Templin at New Kensington. One such machine soon to be seen will test structures of size exceeding 4x7x14 ft. Constant stress testing is preferred to constant strain testing in many services.

In the static testing of structures or structural models, the Beggs hydraulic load maintainer, operating in conjunction with a system of packless hydraulic jacks, has been used in a number of instances in the last year as a commercial method (principally applied to aircraft).

While developing static and dynamic stresses by these various means, the accurate determination of strains becomes important. Many methods are now known but one of peculiar interest has been offered during the past year. This is the wire resistance strain gage and strain rosette known as "SR-4". This makes novel use of the effect of strain in changing the electrical resistance of metallic conductors, but differs radically from past methods in that the

metallic filament is cemented to a carrier, such as paper, and this in turn cemented to the part under test so that it becomes an actual part of the member. In this way, it is possible to reduce effects of temperature and hysteresis so that strain may be measured dependably to better than one millionth of an inch in a one-inch gage length, or in dynamic work at frequencies of over 30,000 cycles per second. This is of an advantage, especially in measuring stresses in gun barrels and in parts of artillery mounts.



The strain gage is so small it can be put in inaccessible places. It adds no weight, requires no extra space, will remain in place any length of time. The most important derivation of this method, especially for stressed skin construction, is the strain rosette containing four gage lines at 45° to each other, cemented as a unit to a surface.

The "stress-coat" paint of ELLIS and DE FOREST of Massachusetts Institute of Technology has been used with success on aircraft engines for much the same purpose. This paint is a brittle lacquer which cracks at points of concentration of stress under static and dynamic loading. The cracked pattern checks closely with strain gage analysis, when used under controlled conditions.

Universal testing machines have been modified to increase convenience, speed of getting out the work, and accuracy.

For work on panels and thin walled structural assemblies for aircraft, the Tate-Emery null method universal testing machine has developed three ranges on a single dial which are interchangeable during test by a 90° turn of knob on the panel board. Testing spaces in the machines have been greatly increased to accommodate structural parts. Added features include ability to maintain the load, accurately, for a long time.

A machine of this type of enormous capacity and speed, capable of investigating the mysteries of hot and cold working of metals, extruding, forging, forming, and rolling, is now in the Aluminum Co. of America's research laboratory. It is known as the Templin precision metal working machine; it has 3,000,000-lb. capacity, operating speed greater than 36 in. per min. at full load, and space within the machine large enough to take the big equipment necessary to carry out these researches. This has been given a great amount of publicity during the year so may be considered ancient history by now!

The interest of the aircraft industry in plastics has stimulated studies in new directions, but one particularly is its impact value (usually in a range below 2 ft-lb.). The study of impact in plastics is an investigation of the resistance of the material to "shatter" from shock loading — rather than a study of notch brittleness, or the effect of low temperature on impact values, as we find in metals.

Analytical Methods

By Thomas A. Wright
Secretary and Technical Director
Lucius Pitkin, Inc.

PERHAPS the most important event of the year to the metallurgical chemist who may read this none too short, but quite inadequate, review has been the emphasis placed by no less an organization than the American Society for Testing Materials on "Newer Tools for the Analytical Chemist" — tools which are known to that select and small group concerned with determinative mineralogy and to others involved in food and organic research but, on the whole, not so well known to workers in routine industrial laboratories. This may well be because so many of the latter type of laboratories tend to be staffed by analysts and laboratory assistants. A busy laboratory-chief, chemist though he be, has little time to ferret out new methods and techniques, and often only his own time to read and study. Sometimes the urge to do so has been killed by the steady pressure of speed, greater output and the higher degree of precision persistently being demanded of a routine analysis — which is obviously a paradox.

Yet the micro-analytical methods of PREGL and EMICH — devised primarily for the organic worker (and what large metallurgical research or industrial laboratory can get along today without at least one good organic analyst or

analytical chemist?) — the methods of CHAMOT and MASON in chemical microscopy, and the spectrograph have so opened up these newer approaches to trouble-shooting, "detective" analyses, or control of contamination and minors — for example only — that the busy control chemist must take heed.

It almost seems that the analytical chemist may yet come into his own, though there are still far too many cases where he is held down by short-sighted purchasing agents or by engineers or chemical superiors to whom an analytical laboratory is a pure out of pocket expense, an analysis something to be made to see that one is not "gypped", or to satisfy a cranky customer, or to be able to compete with the advertising of some more forward looking competitor.

Well, many of these new analytical tools *will* cut expense, they *will* save time, they *can* increase assurance and precision, they *do* permit some things to be done that couldn't be done before. True they often involve the problem of obtaining a representative sample, but that's no worry when all one has available to examine is a speck or a drop. The same may or may not be true of a tarnish or any other type of corrosion problem.

Some of us were privileged to hear, for example, Bell Telephone's BEVERLY CLARKE's masterly and illustrated presentation of "Some Newer Trends in Analytical Chemistry", and Westinghouse Research Lab's own BRUCE ASHCRAFT tell about "Electrochemical Methods in Microchemistry". Dr. CLARKE spoke before the analytical symposium at the A.S.T.M. in June organized by Dr. LUNDELL for Committee E-3 and the analytical division of the American Chemical Society with, incidentally, two guest conductors in the persons of G. FREDERICK SMITH, and Michigan University's HOBE WILLARD. (Incidentally again, why are there so few other noted teachers of analytical chemistry? Can it be because of the almighty dollar, or the small publicity value?)

Dr. ASHCRAFT spoke last October before the Pittsburgh section of the American Electrochemical Society, which has published his paper just recently. Abstracts of Dr. CLARKE's paper, together with others presented at both the chemical and the spectrographic symposia held in June by the American Society for Testing Materials, may be published in forthcoming issues of that Society's *Bulletin*.

Another very worthwhile publication for those chemists who wish to keep abreast of the times is entitled "Microscopic Determination of the Ore Minerals", by M. N. SHORT, Bulletin 914 of the United States Geological Survey (price $1.00 from the Superintendent of Documents, Washington. Get it!)

At one of the most interesting and enlightening joint sessions at the above-mentioned symposia, movies showing production control by the spectrograph at the Ford Plant were presented by H. B. VINCENT of the University of Michigan (see METAL PROGRESS for July 1939), and colored slides by J. D. HANAWALT of microchemical operations at Dow Chemical Co.

The latter company is also giving impetus to X-ray diffraction as another means of ascertaining chemical composition to supplement (and, to quote Dr. CLARKE):

1. Paper technics
   a. Capillary separations
   b. Flange methods
   c. Feigl-B.T.L. spot methods
   d. Contact prints
   e. Paper strip extraction methods
   f. Paper strip separations (zonal impregnation)
   g. Electrography
   h. Classification of useful reactions
2. Polarography
3. Potentiometry
4. Chromatography
5. Radioactive indicators

Last, by no means least, was the excellent illustrated talk on "Industrial Applications of Michrochemistry" by G. L. ROYER of Calco Chemical Co.

Spectrography keeps on growing and spreading. In spectrography precision is being emphasized to an extent that already is affecting beneficially conventional chemical analysis, for when all is said and done spectrographic

(Continued on page 568)

Exposure Chart for Radiography of Steel

By Herbert R. Isenburger

St. John X-Ray Service, Inc., Long Island City, N. Y.

THESE DIAGRAMS are based on the following combination: Pulsating direct current tension generating equipment; line focus, grid action X-ray tube; high speed industrial intensifying screens; blue base safety film; 5 min. development at 65° F.; film density 0.7.

A solution is shown of this problem: "Find the correct exposure on 17-in. film at 36-in. focus-film distance for 3-in. boiler plate of density 7.85 using 220,000 volts and 8 milliamperes."

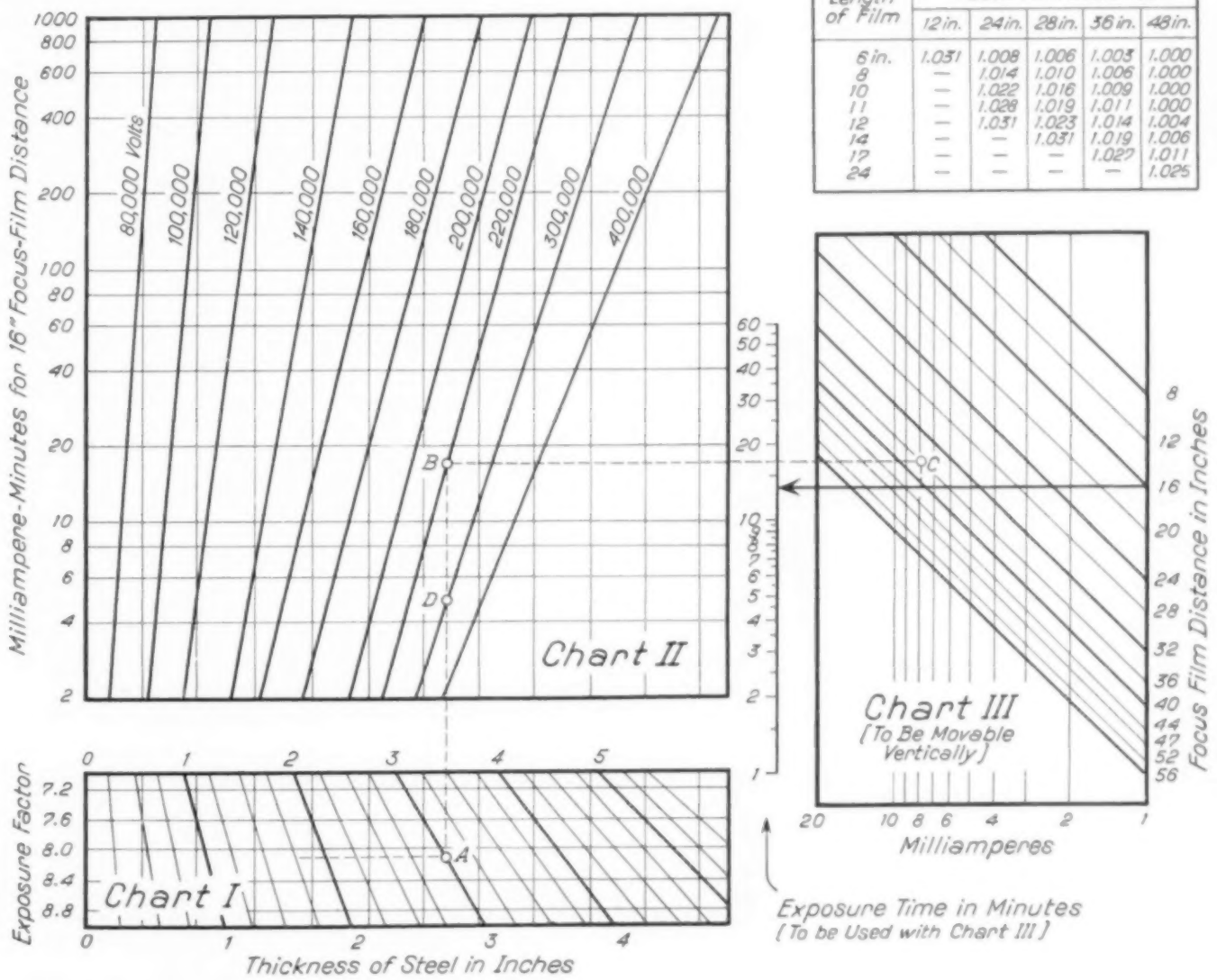
To compute the exposure factor at the ends of films of various lengths and at different focus-film distances, the factors shown in the table are multiplied by the actual density of the steel. In this example the factor 1.027 is located in the column for 36-in. focus-film in the line for 17-in. film. Multiply 1.027 by 7.85, the density of the steel to be radiographed, and the exposure factor is 8.1.

Find intersection of 8.1 with 3-in. line on Chart I (Point A), project upward to voltage of tube (Point B on 220,000-volt line in Chart II). Adjust Chart III so that Point C (corresponding to 36-in. focus-film distance and 8 milliamperes) is opposite Point B, and exposure time is read on central scale against arrow: 13½ min.

Scattered radiation must be filtered to get sharp definition above 250,000 volts, and the use of such filters requires increased exposure times as follows: 10% for 1½ to 2 in. of steel, 20% for 2 to 3 in., 40% for 3 to 4 in., and 50% above 4 in. For instance, suppose the conditions in the above problem remain the same, except a 300,000-volt source is to be used. Adjust Point C opposite Point D and exposure time is found to be 3½ min. without filter, which, increased 20%, comes to 4.2 min.

Table of Exposure Factors

Length of Film	Focus Film Distance				
	12 in.	24 in.	28 in.	36 in.	48 in.
6 in.	1.031	1.008	1.006	1.003	1.000
8	—	1.014	1.010	1.006	1.000
10	—	1.022	1.016	1.009	1.000
11	—	1.028	1.019	1.011	1.000
12	—	1.031	1.023	1.014	1.004
14	—	—	1.031	1.019	1.006
17	—	—	—	1.027	1.011
24	—	—	—	—	1.025



Electrolytic Polishing of Metals

Compiled by G. E. Pellissier, Jr., Harold Markus, and Robert F. Mehl

Metal	Solution	C.D.§	Voltage	Temp. °C.	Time Min.	Remarks	Reference
All carbon steels, martensitic, pearlitic, and sorbitic; Armco and white cast iron; 3% silicon steel	Acetic anhydride, 765 cc. Perchloric acid,* 185 cc. sp.gr. 1.61 (65%) Distilled water, 50 cc. 0.5% Al	4 to 6	50†	<30	4 to 5	Prepare solution 24 hr. before using. Use moderate agitation. Al increases viscosity which permits more vigorous agitation and current density of 3. Can use at current density of 10 for austenitic steels. Prepare samples to 000 paper. Fe or Al cathode.	15
Austenitic steels‡	Acetic anhydride, Perchloric acid (65%) 2 parts to 1 part *	6	50†	<30	4 to 5	Same as above.	15
Iron and silicon-iron	Orthophosphoric acid sp.gr. 1.316	0.6	0.75 to 2.0			Iron cathode.	13
Tin	Perchloric acid * (sp.gr. 1.61), 194 cc. Acetic anhydride, 806 cc.	9 to 15	25 to 40†	15 to 22	8 to 10	Stir solution if length of electrolysis is over 10 min. Polish to 000 paper. Tin cathode. Electrodes 2 cm. apart.	12
Copper‡	Orthophosphoric acid sp.gr. 1.3 to 1.4	0.65 to 0.75	2	Room	>5	Polish to 0000. Copper cathode. Electrodes 2.2 cm. apart.	7
Copper‡	Pyrophosphoric acid 530 g. per l.	8 to 10	1.6 to 2.0	15 to 22	10 to 15	Polish to 00000 paper. Copper cathode.	5
Cobalt	Orthophosphoric acid sp.gr. 1.35		1.2			Rough metallographic polish. Cobalt cathode.	11
Aluminum‡	Perchloric acid * (sp.gr. 1.48) Acetic anhydride, 2 parts to 7 parts	3.0 to 5.0	50 to 100†	<50	15	Allow 4 to 5 g. per l. to enter solution. Polish to 000 paper. Aluminum cathode.	8
Zinc‡	Potassium hydroxide 25% solution	16	6	Room	15	0000 paper. Solution agitated by air or nitrogen. Copper cathode. Electrodes 2.5 to 15 mm. apart.	10
Lead	Acetic acid, 650 to 750 cc. Perchloric acid,* 350 to 250 cc.	1 to 2			3 to 5	0000 paper, horizontal anode. Use current density of 20 to 25 for 1 to 2 min. to remove flowed layer. Copper cathode.	5
Pb-Sn alloy	Same as above	2					5
Tin + 3% Sb	Same as for tin, above	9 to 15	25 to 40†	15 to 22	8 to 10	Same as for tin, above.	12
Copper + 3.2% Co Copper + 2.4% Fe	Orthophosphoric acid sp.gr. 1.35	0.07	2		5 to 10	Polish to 000 paper. Copper cathode. Electrodes horizontal and ½ in. apart.	14
Brass, 70-30,‡ (1 constituent)	Orthophosphoric acid 430 g. per l.	13 to 15	1.9				5
66.7-33.3 Brass‡	Orthophosphoric acid 990 g. per l.	2.5 to 3					5
Two-constituent 60-40 brass ‡	Pyrophosphoric acid 530 g. per l.	9 to 11	1.9				5
Aluminum bronze; Leaded bronze (85 Cu, 10 Sn, 3 Zn, 2 Pb)	Orthophosphoric acid 990 g. per l.	1 to 2					5
Phosphor bronze, silicon bronze, monel, nichrome, nickel, and ‡ metals	Methyl alcohol (abs.), Nitric acid (conc.), 2 parts to 1 part		40 to 50†	20 to 30	Seconds	Cathode of stainless steel cloth in bottom of dish. Distance between electrodes ½ to 1 in.	17

*Explosive Mixture! Mix slowly; keep cold. Do not use with bakelite or lucite mountings, or with bismuth alloys.

§Current density in amperes per square decimeter. †External applied voltage. ‡See last item in table.

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Instruments for Control and Analysis of Controlled Atmospheres

By E. E. Slowter
Chemical Engineer
and B. W. Gonser
Metallurgist
Battelle Memorial Institute

NEED FOR MAINTAINING CONTROL over furnace atmospheres used in the heat treatment of metals has become more pronounced with the widespread use of special atmospheres. Early work was conducted largely on a cut-and-try basis; a batch of metal was treated in a certain atmosphere, then examined. Adjustment of the atmosphere proceeded according to the ideas of the experimenter until a satisfactory product was secured or patience exhausted, then the valve settings of the atmosphere producer were noted and the operator piously (or occasionally profanely) hoped the same results would be secured the next time he used the same settings!

It is still practical to use the hit-and-miss system for installations where auxiliary equipment must be kept at a minimum, but apparatus for analyzing and controlling the atmosphere at all times is available to eliminate guesswork and assure proper conditions. A large store of fundamental information on the behavior of various metals in atmospheres of varied composition has been accumulated, and much time and material can often be saved by correlating this information with the available plant conditions. Some knowledge of the atmosphere composition and how it changes is needed to apply this information to specific plant problems.

To answer the user's questions, "Is this the right atmosphere for the material I want to heat, and, if so, how can I keep it correct?" the manufacturer of control equipment must obtain either a direct or an indirect measure of the effect of the atmosphere upon the work. A *direct* measurement actually determines the effect of the atmosphere, while an *indirect* method gives a measurement of some quality of the atmosphere which can be correlated with its direct effect on the work. Thus, the exact chemical composition of the atmosphere need not be known to control it. Since the important reactions between an atmosphere and the work are primarily chemical, however, the chemical composition of the atmosphere is really the basic measure of its effect.

Many interesting and effective controls have been developed in the past few years. Since much of this equipment has been competitive and some made primarily for another purpose, it has seemed desirable to compile an outline of the available control equipment to aid those interested in controlled atmospheres in learning what is available and to assist in evaluating different instruments for specific purposes. At the invitation of the Editor of METAL PROGRESS the Battelle Memorial Institute has sponsored the collection of this information and the various instrument companies have generously cooperated. They have been quite frank in describing the limitations as well as the possibilities of their equipment — a far-sighted stand which does them much credit.

It is the purpose of this article to show the basic principles used for control rather than specific mechanical devices. Various types of analytical and control equipment now commercially available for controlled atmosphere use are consequently described, but other devices operating on the same principle with only minor differences in the operating mechanism have not been mentioned, as well as modifications of a given instrumental type.

Means for Controlled Atmosphere Analysis

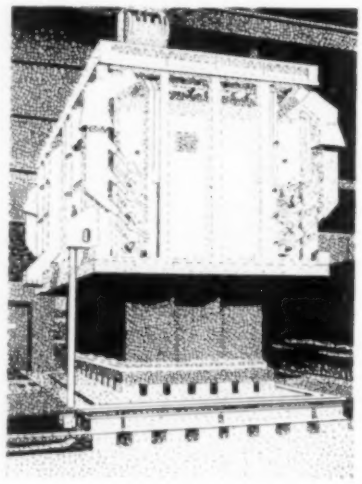
Since an analysis of a controlled atmosphere does not necessarily mean that its composition must be determined, the following methods (and possibly others) may be used:

1. *Composition Analysis by Chemical Means:* When the composition of a controlled atmosphere is completely known its effect upon the material being heat treated at a given temperature may be predicted from other data.

2. *Partial Composition Analysis by Chemical Means:* If some component of a controlled atmosphere bears a reasonably fixed relation to the other components, the performance of the atmosphere

may be predicted from a measure of this component. Also, where only one component of a gas mixture is particularly detrimental, analysis for that component only is sufficient.

3. *Physical Property Determination:* For a given type of gas produced in some particular machine the physical properties of that gas bear a relation to its chemical composition which may be used for control purposes. Gas density, thermal conductivity, and heating value are properties commonly measured.



4. *Effect Determination:* The atmosphere may actually be tried on the material being heat treated (usually in small scale tests) to determine its effect, with subsequent adjustment and control.

In all these methods, although the atmosphere composition may not actually or completely be determined, it is necessary to know the direction of change in the atmosphere composition which is followed by the instrument. Thus, in all methods, measurement and control of the atmosphere must be correlated with the composition although, using a well-designed instrument, the operator may not be conscious of the fact that this is being done.

Since many controlled atmospheres are produced by combustion processes it is not surprising that the controls have been borrowed from or derived from the combustion engineer's tools. However, the relatively greater importance of the amounts of certain gases and the effects of small amounts of other gases in controlled atmosphere work has required many refinements in this equipment. In this paper the means of analysis of the atmosphere has been used as the means of classification.

Composition Analysis by Chemical Means

The most important constituents which may be found in controlled atmospheres are:

Nitrogen (N_2), hydrogen (H_2), oxygen (O_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), water vapor (H_2O) and hydrogen sulphide (H_2S). The large number and relative importance of each of these has made any sort of universal, automatic gas analyzer practically impossible; even manually operated devices fail to analyze for all of them. The best shop equipment now available is the Orsat type of gas analyzer which, when used with a combustion pipette, will determine CO_2, O_2, CO, H_2, CH_4 (and N_2 by difference). The other two important components, H_2O and H_2S, must be measured by separate instruments. The Orsat instrument is so well known to all who have had some elementary chemistry that no description is necessary here.

While a combination of instruments may give a complete analysis of a controlled atmosphere, the equipment requires an experienced operator and a considerable amount of time for each analysis. This is unsatisfactory for most commercial applications where a simple, easily read, continuous recording or controlling device is required. For such purposes a partial analysis of the atmosphere may be satisfactory but the user should always remember that he should take such partial analyses with reservations when unexpected or unusual operating conditions occur.

Partial Analyses by Chemical Means

Carbon Dioxide: This gas is relatively easy to determine. Many absorption type meters have been developed in fuel combustion work to indicate and record this gas. Absorption devices all depend upon the measurement of the decrease in volume of a fixed amount of sample when the CO_2 is scrubbed out. However, for most controlled atmosphere applications the measurement of CO_2 only, in the amounts detectable by such devices, does not provide a critical value by which the atmosphere may be evaluated. For this reason a description of the available instruments is not considered pertinent. If a specific application is found where such an instrument is suitable, a large amount of information is readily available.

Oxygen: Oxygen is an important element in a controlled atmosphere (in most cases it is desired that free oxygen be absent). A new and interesting type of oxygen recorder has recently been developed and patented by Mine Safety Appliances Co. This device may be used provided CO_2 is first removed from the gas sample. It measures the oxidizing power of an atmosphere on a copper electrode and this serves as a measure of its oxygen content. The essential parts of this recorder are a voltaic cell, made of cast hard rubber, containing an electrolytic solution (which is a strong reducing agent) and two electrodes of pure cop-

per. One electrode in bar form is completely immersed while the other, which is in ring form, slowly revolves with a part of its periphery submerged in the electrolyte and the remainder exposed to the prepared sample of gas which flows through the cell above the electrolytic solution. The oxygen in the sample reacts with the exposed copper surface of this rotating ring and forms copper oxide. As the ring rotates the copper oxide enters the solution and a potential is set up between the copper oxide and the submerged electrode, and measured by a potentiometer calibrated to read the oxygen content of the sample. Within reasonable limits it is said that this potential is not influenced by the *rate* of sample flow. These recorders are obtainable to measure ranges from zero up to 2.5% oxygen or from zero up to 20.8%.

A schematic diagram of this apparatus is shown in Fig. 1. The scrubbing system at top right is used to condition the gas; first and third towers contain alkaline material for removing acid gases such as CO_2. The fourth tower contains glass wool which acts as a mechanical filter to remove any entrained mist. An oxygen-absorbing material in the second tower is used to remove oxygen from the sample when setting the instrument to zero; this second tower is connected by two 3-way valves so that the sample can be by-passed around the first bubbler and through the second one. When thus conditioned the sample is ready for analysis, since hydrocarbons and other non-acid gaseous products do not interfere.

The purified sample then passes through a flow meter to the electrolytic cell. The electrolyte consists of a special solution of ammonium chloride (NH_4Cl), ammonium hydroxide (NH_4OH), and ammonium carbonate ($[NH_4]_2CO_3$) to which there has been added a small quantity of ammoniocupric ions. This solution is held at a constant level in the voltaic cell by a large overflow and is recirculated from a solution container by a pump.

Hydrogen Sulphide: In practically all applications of controlled atmospheres sulphur-bearing gases are very undesirable. This is particularly true when annealing copper and its alloys. If there is sulphur in the fuel used, it is preferably removed before the fuel is burned to produce a controlled atmosphere. Since most controlled atmospheres are on the reducing side of perfect combustion, any sulphur present exists as hydrogen sulphide. It can be detected by its odor and by reaction with lead acetate, but these tests are only qualitative.

For quantitative measurements, a detector is also marketed by Mine Safety Appliances Co. This detector was originally developed for measuring hydrogen sulphide in industrial atmospheres and is described in U. S. Bureau of Mines' Report of Investigations No. 3276, June, 1935. Within its range of accuracy it may also measure hydrogen sulphide in furnace atmospheres. The normal instrument covers the range of zero to 0.04% H_2S, or about 0 to 25 grains per 100 cu.ft. of gas, and is sensitive to about ½ grain of H_2S per 100 cu.ft. A special detector tube is also made for the range of 0 to 50 parts of H_2S per million parts of sample (about 0 to 3 grains per 100 cu.ft.), and sensitive to approximately 5 parts of H_2S per million of sample.

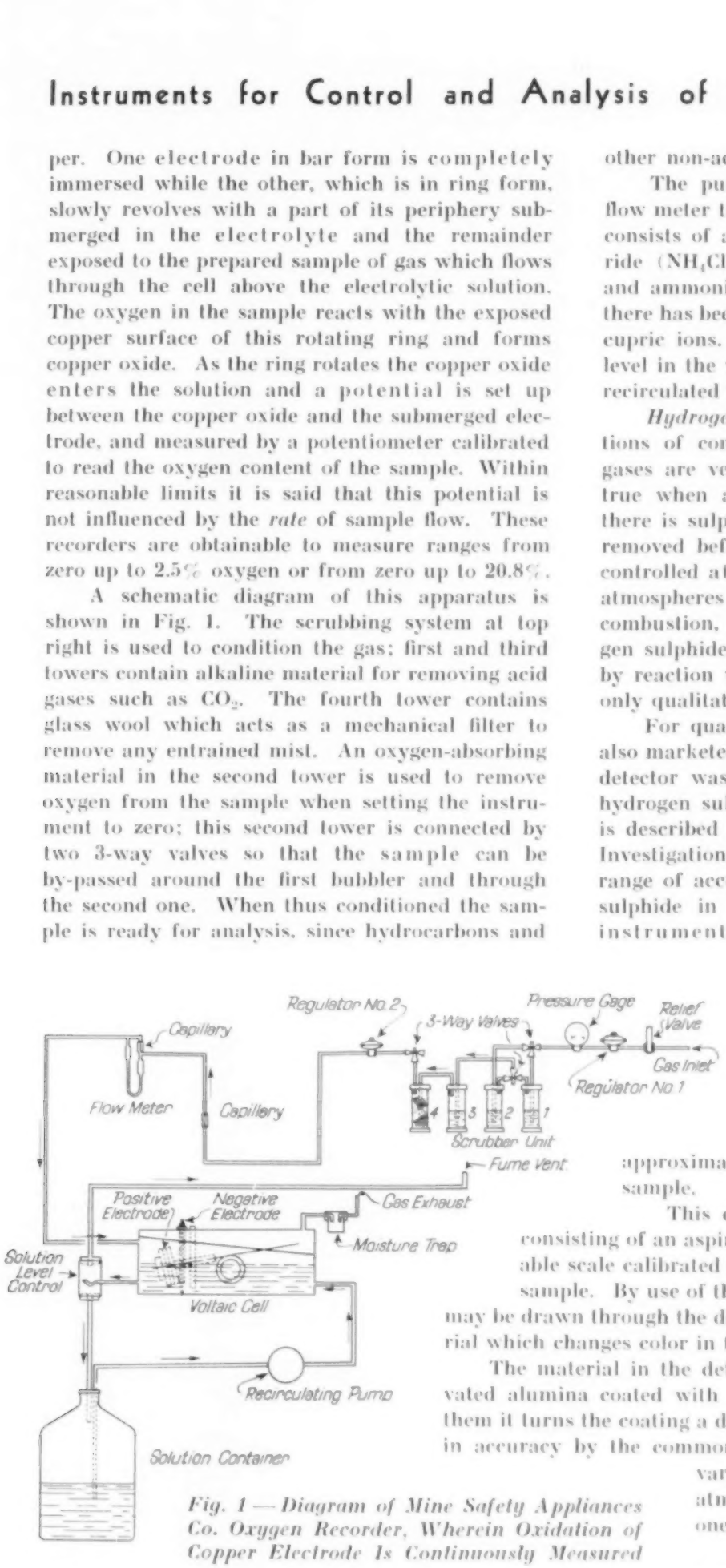


Fig. 1 — Diagram of Mine Safety Appliances Co. Oxygen Recorder, Wherein Oxidation of Copper Electrode Is Continuously Measured

This detector is a hand-operated device consisting of an aspirator bulb, a detector tube and a movable scale calibrated to read the amount of H_2S in a given sample. By use of the aspirator a fixed amount of sample may be drawn through the detector tube, and the amount of material which changes color in the tube is a measure of the H_2S.

The material in the detector tube is sized granules of activated alumina coated with silver cyanide. As H_2S passes over them it turns the coating a dark gray. The reagent is not affected in accuracy by the commonly occurring gases, water vapor or variations in temperature within the atmospheric range, but is usable for but one analysis.

Hermetically sealed detector tubes are secured from the manufacturer of

Crystallography of the Chemical Elements

As Tabulated by William Hume-Rothery
in "The Structure of Metals and Alloys" Monograph No 1, British Institute of Metals

Element Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio c ÷ a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter (Coordination No. 12)
Group IA in Periodic Sequence									
3 Lithium	(2)1	⊞	—	8	3.51±0.04	—	3.04	—	3.13
11 Sodium	(2)(8)1	⊞	—	8	4.30±0.04	—	3.72	—	3.83
19 Potassium	(2)(8)(8)1	⊞	—	8	5.333 5	—	4.618	—	4.76
37 Rubidium	(2)(8)(18)(8)1	⊞	—	8	5.62±0.03 at -173°C.	—	4.87 at -173°C.	—	5.02
55 Cesium	(2)(8)(18)(18)(8)1	⊞	—	8	6.05±0.03 at -173°C.	—	5.24 at -173°C.	—	5.40
87 Virginium	(2)(8)(18)(32)(18)(8)1	—	—	—	—	—	—	—	
Group IB									
29 Copper	(2)(8)(18)1	⊡	—	12	3.607 8	—	2.551 1	—	2.551
47 Silver	(2)(8)(18)(18)1	⊡	—	12	4.077 8	—	2.883 5	—	2.883
79 Gold	(2)(8)(18)(32)(18)1	⊡	—	12	4.069 9	—	2.877 8	—	2.877
Group IIA in Periodic Sequence									
4 Beryllium	(2)2	⬡	1.584 8	6,6	2.267 9	3.594 2	2.223 5	2.267 9	2.25
12 Magnesium	(2)(8)2	⬡	1.6236	6,6	3.202 2	5.199 1	3.190 0	3.202 2	3.20
20 Calcium	(2)(8)(8)2	α = ⊡	—	12	5.56	—	3.93	—	3.93
(data for 450°C.) →		β = ⬡	1.640	6,6	3.94	6.46	3.94	3.955	3.98
38 Strontium	(2)(8)(18)(8)2	⊡	—	12	6.07 5	—	4.29 6	—	4.29 6
56 Barium	(2)(8)(18)(18)(8)2	⊞	—	8	5.01 5	—	4.34 3	—	4.48
88 Radium	(2)(8)(18)(32)(18)(8)2		—	—	—	—	—	—	—
Group IIB									
30 Zinc	(2)(8)(18)2	⬡	1.8560	6,6	2.659 0	4.935 1	2.659 0	2.906 1	2.748
48 Cadmium	(2)(8)(18)(18)2	⬡	1.885 2	6,6	2.973 6	5.606 9	2.973 6	3.287 2	3.042
80 Mercury	(2)(8)(18)(32)(18)2	□	α = 70°31.7'	6	2.999 ← at -46°C.		2.999	—	3.10
Group IIIA in Periodic Sequence									
5 Boron	(2)3		—	—	—	—	—	—	2.80 to
13 Aluminum	(2)(8)3	⊡	—	12	4.041 4	—	2.856 8	←	2.86 (note b)
21 Scandium	(2)(8)(9)2		—	—	—	—	—	—	
39 Yttrium	(2)(8)(18)(9)2	⬡	1.588	6,6	3.663	5.814	3.595	3.663	3.629
57 Lanthanum	(2)(8)(18)(18)(9)2	α = ⬡	1.613	6,6	3.754	6.063	3.727	3.754	3.741
		β = ⊡		12	5 296		3.754		3.745
89 Actinium	(2)(8)(18)(32)(18)(9)2		—	—	—	—	—	—	—
Group IIIB									
31 Gallium	(2)(8)(18)3	▯	—	—	4.5167	7.6448	(note c)	—	—
		a ÷ b ÷ c = 1 : 0.99868 : 1.69257			b = 4.5107				
49 Indium	(2)(8)(18)(18)3	◬	1.077	4,8	4.583	4.936	4 at 3.241	8 at 3.368	3.138
81 Thallium	(2)(8)(18)(32)(18)3	α = ⬡	1.600	6,6	3.450	5.520	3.404	3.450	3.427
		β = ⊡	—	12	4.841	—	3.423	—	3.423

Notes: (a) ⊞ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close packed hexagonal; □ is simple rhombohedral; ▯ is orthorhombic; ◬ is face-centered tetragonal

(b) Appears to be smaller in some alloys

(c) 8 atoms to unit cell; each atom has 1 neighbor at 2.437, 2 at 2.706, 2 at 2.736 and 2 at 2.795

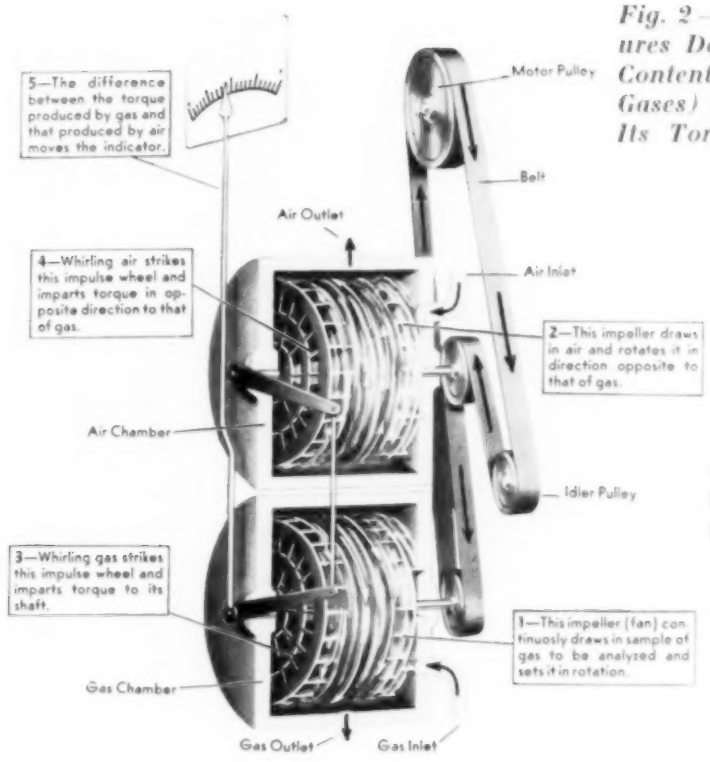

5—The difference between the torque produced by gas and that produced by air moves the indicator.
Motor Pulley
Belt
Air Outlet
Air Inlet
4—Whirling air strikes this impulse wheel and imparts torque in opposite direction to that of gas.
2—This impeller draws in air and rotates it in direction opposite to that of gas.
Air Chamber
Idler Pulley
3—Whirling gas strikes this impulse wheel and imparts torque to its shaft.
1—This impeller (fan) continuously draws in sample of gas to be analyzed and sets it in rotation.
Gas Chamber
Gas Outlet
Gas Inlet

Fig. 2 — "Ranarex" Recorder, by the Permutit Co., Measures Density of Gas (and Inferentially Its Proportional Content of Heavy Oxidizing Gases and Light Reducing Gases) by Using It in a "Fluid-Drive" and Opposing Its Torque to That Produced by Atmospheric Air

the device. When ready to make an analysis the ends of the tube are broken off, it is inserted in the holding device and the calibrated scale is adjusted so that its zero is opposite the beginning of the reagent granules. The test is then made by squeezing the aspirator bulb ten times, allowing the bulb to expand completely after each aspiration. The amount of hydrogen sulphide in the sample is then read on the calibrated scale at the end of discoloration. As in all gas analyzers, care must be taken to see that the proper sample is available at the inlet of the device.

Physical Property Determination

In all devices for analyzing controlled atmospheres on the basis of their physical properties the instrument user must recognize the fact that atmospheres of widely different chemical composition may have certain physical properties which are identical. For this reason a given value of a physical property for one atmosphere does not mean that another atmosphere having the same value for that physical property will have the same effect on heated metal. However, such physical property determinations are of value, since — for a given installation — changes in the physical property being measured can frequently be correlated with changes in the gas composition. It is not a fool-proof method, however, since composition changes may be compensating and an important change in the gas composition may not register, or if it does register it may be misinterpreted by the operator.

Specific Gravity: Since the specific gravity of the various components of a controlled atmosphere are not the same, its specific gravity may be used to measure the approximate change in its composition. As an example, the specific gravities (compared to air = 1.000) of the common gases are:

Gas	Specific Gravity
CO_2	1.529
O_2	1.105
N_2	0.966
CO	0.966
CH_4	0.552
H_2	0.069

The specific gravity of any particular atmosphere is a function of the specific gravities and amounts of its components. In the "Ranarex" indicators and recorders made by the Permutit Co. a rotating fan forces the unknown gas against an impulse wheel which faces the fan and is located in the same chamber, thus producing a torque proportional to the specific gravity of the gas (and, therefore, under certain conditions, proportional to the composition of the gas). Since an absolute measure of torque would be affected by many variables, this instrument compares it with the torque produced by air, as shown in Fig. 2. The unknown gas and air are both passed (separately) through a humidifier to bring them to the same temperature and humidity; suitable gas purification is also used in advance of the instrument. The two impulse wheels are linked and a pointer measures the difference in torque and thereby the specific gravity of the unknown gas as compared to air. This instrument is rugged and works on purely physical principles thereby eliminating any chemical reactions. However, any elements affecting the specific gravity of the gas other than those for which the instrument was designed will cause erratic readings and the application must be selected with this in view.

Thermal Conductivity: Of the common gases, N_2, O_2 and CO have about the same thermal conductivity (taken as about unity) while CH_4, H_2O (vapor), and H_2 have thermal conductivities greater than unity and CO_2 a value less than unity. Changes in their relative amounts therefore pro-

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Element — Atomic No.	Electron Arrangement in Free Atoms	Crystal Structure (note a)	Axial Ratio c ÷ a	Coordination No.	Lattice Constant a	Lattice Constant c	Interatomic Distance d_1	Interatomic Distance d_2	Atomic Diameter (Coordination No. 12)
Group IVA in Periodic Sequence									
22 Titanium	(2)(8)(10)2	⬡	1.601	6,6	2.953	4.729	2.915	2.953	2.93
40 Zirconium	(2)(8)(18)(10)2	α=⬡	1.589	6,6	3.223	5.123	3.166	3.223	3.19
(data for 867°C.)		β=⧈	—	8	3.61	—	3.126	—	—
72 Hafnium	(2)(8)(18)(32)(10)(2)	⬡	1.587	6,6	3.200	5.077	3.139	3.200	3.17
90 Thorium	(2)(8)(18)(32)(18)(10)(2)	⊡	—	12	5.077 or 5.091	—	3.590 or 3.600	—	—
Group IVB, Including Carbon and Silicon									
6 Carbon, diamond	(2)4	◇	—	4	3.5606	—	1.5113	—	—
graphite	—	⬡ (b)	2.75	6	2.46	6.78	1.42	2.46	—
14 Silicon	(2)(8)4	◇	—	4	5.418	—	2.346	—	—
32 Germanium	(2)(8)(18)4	◇	—	4	5.647	—	2.445	—	2.788
50 Tin, gray	(2)(8)(18)(18)4	◇	—	4	6.46	—	2.797	—	3.164
white	—	△	0.5456	4,2	5.8194	3.1753	3.0161	3.1753	—
82 Lead	(2)(8)(18)(32)(18)4	⊡	—	12	4.9389	—	3.4923	—	3.494
Group VA in Periodic Sequence									
23 Vanadium	(2)(8)(11)2	⧈	—	8	3.033	—	2.627	—	2.69
41 Columbium	(2)(8)(18)(12)1	⧈	—	8	3.294 ±0.001	—	2.853	—	2.94
73 Tantalum	(2)(8)(18)(32)(11)2	⧈	—	8	3.298 ±0.002	—	2.854	—	2.94
91 Protoactinium	(2)(8)(18)(32)(18)(11)2		—	—	—	—	—	—	—
Group VB									
7 Nitrogen	(2)5	α=cubic	—	—	5.66	—	1.06	—	—
15 Phosphorus	(2)(8)5	▱	α=34° 7′	3,3	5.14	—	1.74	3.01	—
33 Arsenic	(2)(8)(18)5	▱	α=53°49′	3,3	4.151	—	2.5086	3.1465	—
51 Antimony	(2)(8)(18)(18)5	▱	α=57° 5′	3,3	4.497	—	2.879	3.378	3.228
83 Bismuth	(2)(8)(18)(32)(18)5	▱	α=57°16′	3,3	4.7365	—	3.105	3.474	3.64
Group VIA in Periodic Sequence									
24 Chromium	(2)(8)(13)1	α=⧈	—	8	2.8786	—	2.4929	—	2.57
		β=⬡	1.626	6,6	2.717	4.418	2.709	2.717	2.71
42 Molybdenum	(2)(8)(18)(13)1	⧈	—	8	3.1403	—	2.7196	—	2.80
74 Tungsten	(2)(8)(18)(32)(12)2	α=⧈	—	8	3.1583	—	2.7352	—	2.82
		β, (c)	8 atoms in unit cell →		5.038		2.519	2.816	
92 Uranium	(2)(8)(18)(32)(18)(12)2	Mono-clinic	a÷b÷c=1÷1.73÷1.17 β=64°18′		2.829	3.308 b=4.887	2.829 ← Note d		—
Group VIB									
8 Oxygen	(2)6	—	—	—	—	—	—	—	—
16 Sulphur	(2)(8)6	▯ (d)	2.315	—	10.61	24.56	—	—	—
34 Selenium	(2)(8)(18)6	⬡ (e)	1.140	2,4	4.337	4.945	2.316	3.457	—
52 Tellurium	(2)(8)(18)(18)6	⬡ (e)	1.33	2,4	4.445	5.912	2.858	3.46	—
84 Polonium	(2)(8)(18)(32)(18)6	—	—	—	—	—	—	—	—

Notes: (a) ⧈ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close packed hexagonal except as noted; ◇ is diamond; △ is tetragonal; ▱ is rhombohedral and ▯ is orthorhombic

(b) Graphite is hexagonal, not close packed, with four atoms per unit cell.

(c) Cubic structure; two positions distinguishable, X and Y. Each atom X has 12 Y at 2.816 Å; each atom Y has 2 Y at 2.519 and 4 X at 2.816 Å

(d) 128 atoms in unit cell. Data from International Critical Tables or A.S.M. Metals Handbook

(e) Hexagonal, not close packed; each atom has 2 neighbors at d_1 and 4 at d_2

duce changes in the thermal conductivity of an atmosphere containing them, and by measuring the thermal conductance of a controlled atmosphere, changes in its composition can be detected. It is important to note that it is the *change* in the thermal conductance of a gas of one type produced by a given generator which is important, and not the absolute value of the conductance of the gas, since gases of widely different composition may have the same thermal conductance. Also, thermal measurements of an atmosphere are not particularly suitable for operation in the approximate region of perfect combustion, but in most controlled atmosphere applications it is not desirable to operate at this point anyway.

One instrument manufactured by Brown Instrument Co. of this type employs an alternating current Wheatstone bridge with two arms of the bridge in the unknown gas and two arms sealed in an air space (Fig. 3). An a.c. galvanometer shows any unbalance of the bridge, and in this case is connected to a balancing slide wire and recording pen so that a record of the thermal conductivity of the unknown gas may be made. The arms making up the bridge are of platinum, which

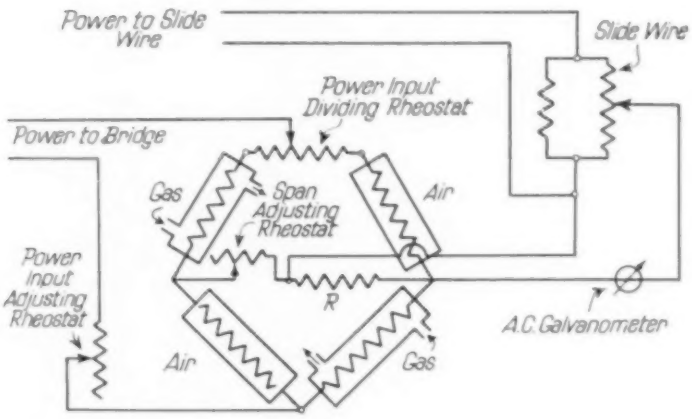

Fig. 3 — Brown Instrument Co.'s "Analy-Graph" Uses Hot Wires in the Form of a Wheatstone Bridge to Measure the Thermal Conductivity of a Gas Atmosphere and Thus Record Any Important Change in Major Constituents

has a fairly high temperature coefficient of resistance. Current is supplied to the bridge arms at a value, regulated by the power input adjusting rheostat, to heat them to about 100° C. A power dividing rheostat is used to adjust the currents to the respective arms of the bridge.

With the device properly balanced by the power input dividing rheostat, air in the sample chamber will cause the wires in that chamber to be at such a temperature that there will be no unbalance in the bridge circuit composed of these two wires and the two wires sealed in the air chamber. When a gas other than air enters the gas sample chamber the heat conductivity of the gas surrounding the heated wire is representative of that gas instead of air and the temperature of the platinum wires or coils rises or falls depending upon the conductivity of the unknown gas. This change in temperature causes the resistance of the wires to change, thereby unbalancing the circuit, and the unbalanced Wheatstone bridge causes a current to flow through resistor *R* and the voltage drop across this resistor moves the galvanometer needle. The instrument then acts automatically to bring the circuit into balance by moving the contact along the slide wire until the voltage between the end of the slide wire and the contact balances the voltage drop across resistor *R*. When properly adjusted the indicating pointer will then indicate a reading which is in relation to the thermal conductivity of the gas in the gas sample cell. To secure constancy of results, gold plated cells are used.

The gas flow of the sample through the cells is secured by a water aspirator or suction pump. The furnace gas first passes through a water cooled surface condenser, a calcium chloride drier and a cellulose filter before reaching the thermal conductivity cell; thereafter it goes to a bubble bottle, a flow gage and finally through the aspirating or pumping device. Only a portion of the gas aspirated actually passes through the cell proper, the bulk of the gas being by-passed so that fairly wide variations in the total gas flow do not produce erratic results. Since in reducing atmospheres the apparatus is most sensitive to hydrogen, and in oxidizing atmospheres to CO_2, two scales are provided on the instrument.

While this device was originally developed as an indicating and recording instrument, a circuit for controlling the composition of a controlled atmosphere produced by the partial combustion of a fuel gas has been developed by Brown Instrument Co. and by C. M. Kemp Mfg. Co. The potentiometer is connected with the gas producing unit so as to hold the atmosphere at any predetermined thermal conductivity. In the Kemp "Industrial Carburetor" the gas producing unit mixes the gas and air for combustion in a special carburetor, which in its simplest form consists of a slide valve movable in two dimensions. Movement in one dimension controls volume at a substantially constant composition, while movement in the other dimension controls composition at a substantially constant volume. The controlling potentiometer

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Group VII A in Periodic Sequence									
25 Manganese	(2)(8)(13)2	α = Cubic (note b)	—	—	8.894	—	—	—	—
		β = Cubic (note c)		12	6.300	—	—	—	—
		γ = △	0.934	—	3.774	3.526	2.582	2.669	—
43 Masurium	(2)(8)(18)(14)1	—	—	—	—	—	—	—	—
75 Rhenium	(2)(8)(18)(32)(13)2	⬡	1.6148		2.7553	4.4493	2.7349	2.7553	2.75
Group VII B									
9 Fluorine	(2)7	—	—	—	—	—	—	—	—
17 Chlorine	(2)(8)7	—	—	—	—	—	—	—	—
35 Bromine	(2)(8)(18)7	—	—	—	—	—	—	—	—
53 Iodine	(2)(8)(18)(18)7	▯	a÷b÷c = 1÷1.51÷2.04		4.795	9.780 b = 7.255	2.70	(note d)	—
85 Alabamine	(2)(8)(18)(32)(18)7	—	—	—	—	—	—	—	—
Group VIII in Periodic Sequence									
26 Iron	(2)(8)(14)2	α = ⧈	—	—	2.861o	—	2.4777	—	—
		γ = ⊡	—	—	3.64 ← at 900°C.		2.580	—	2.52
27 Cobalt	(2)(8)(15)2	α = ⬡	1.624	—	2.507	4.072	2.499	2.507	2.50
		β = ⊡	—	—	3.545	—	2.507	—	2.507
28 Nickel	(2)(8)(16)2	α = ⬡	1.64	—	2.49	4.08	2.49	2.49	2.49
		β = ⊡	—	—	3.5170	—	2.4869	—	2.487
44 Ruthenium	(2)(8)(18)(15)1	⬡	1.585	—	2.695	4.273	2.643	2.695	2.67
45 Rhodium	(2)(8)(18)(16)1	⊡	—	—	3.7955	—	2.6838	—	2.684
46 Palladium	(2)(8)(18)(18)-	⊡	—	—	3.8824	—	2.7453	—	2.745
76 Osmium	(2)(8)(18)(32)(14)2	⬡	1.578	—	2.730	4.309	2.669	2.730	2.70
77 Iridium	(2)(8)(18)(32)(15)2	⊡	—	—	3.8312	—	2.7091	—	2.709
78 Platinum	(2)(8)(18)(32)(16)2	⊡	—	—	3.9158	—	2.7689	—	2.769
Rare Earth Group									
58 Cerium	(2)(8)(18)(19)(9)2	α = ⬡	1.62	6,6	3.65	5.91	3.63	3.65	3.64
		β = ⊡	—	12	5.143	—	3.637	—	3.637
59 Praseodymium	(2)(8)(18)(20)(9)2	⬡	1.620	6,6	3.657	5.924	3.638	3.657	3.65
60 Neodymium	(2)(8)(18)(21)(9)2	⬡	1.608	6,6	3.657	5.88	3.619	3.657	3.64
68 Erbium	(2)(8)(18)(29)(9)2	⬡	1.63	6,6	3.74	6.09	3.73	3.74	3.73

Notes: (a) ⧈ is body-centered cubic; ⊡ is face-centered cubic; ⬡ is close-packed hexagonal; ▯ is orthorhombic

(b) Approximates ⧈ where each lattice point is a cluster of 29 atoms; 1 type X, 4 type A, 12 type D_2 and 12 type D_1. The X atoms occupy the largest volume and the D_2 the smallest. Interatomic distances of neighboring atoms are as follows:

X atoms have 12 D_2 at 2.71
4 A at 2.82

A atoms have 1 X at 2.82
3 D_1 at 2.49 and 3 at 2.96
3 D_2 at 2.69 and 3 at 2.89

D_2 atoms have 1 X at 2.71
2 A at 2.69 and 1 at 2.89
1 D_2 at 2.24 and 2 at 2.38
1 D_1 at 2.45, 2 at 2.51 and 2 at 2.66

D_1 atoms have 1 A at 2.49 and 1 at 2.96
1 D_2 at 2.45, 2 at 2.51 and 2 at 2.66
6 D_1 at 2.67

(c) Complicated structure with 20 atoms of two kinds in unit cell.

Each atom of the first kind has
3 neighbors at 2.365
3 " " 2.530
3 " " 2.671
3 " " 2.675

Each atom of the second kind has
2 neighbors at 2.530
2 " " 2.615
4 " " 2.659
2 " " 2.671
2 " " 2.675

(d) Atoms arranged in pairs so that each one has one close neighbor at 2.70. Data from A.S.M. Metals Handbook.

acts upon a motor geared to a micrometer adjusting screw upon the carburetor and thereby adjusts the gas-air ratio so as to secure a gas composition of constant thermal conductivity and, for a given apparatus and fuel gas, of a substantially constant composition.

Heating Value: A device of this type is only suitable for atmospheres containing combustible gases. In it a sample is mixed with a predetermined amount of air and the heat of combustion measured. The combustibles determined depend upon the method of combustion. In one type of device the heat of combustion is made a measure of the ($CO + H_2$) content of the gas, since these are the usual unburned gases encountered in the applications for which this instrument is designed. The summation of the two is approximately correct, since their heats of combustion are about equal. Methane (CH_4) is not correctly indicated by such an instrument, as it is difficult to secure catalytic combustion of this gas.

In this particular type of device (manufactured by Bacharach Industrial Instrument Co.) combustion occurs at the surface of a platinum wire. The unknown gas and air are pulled into the apparatus at a constant rate and mixed in a predetermined ratio. About 95% of this mixed gas is vented through an orifice, speeding up the flow and giving a constant head or pressure to the supply going to the analyzing system, whereby the latter is kept under a positive pressure. The remaining 5% of the gas is passed through the analyzing system and moves at a constant velocity through a lead-lined gas cell containing an electrically heated platinum wire. The combustible gases are burned catalytically along this wire, thereby raising its temperature and its electric resistance is then compared with that of an identical wire mounted in a sealed air cell.

These two platinum wires are arranged so as to form two arms of a Wheatstone bridge while two constant resistances form the other two arms, as shown in Fig. 4. In setting up the apparatus the current is set at a predetermined value by the current adjusting rheostat and the instrument is zeroed with a balancing potentiometer when air is passing through the gas cell. (This potentiometer is not shown in the drawing but its resistance is inserted between the two cells while the variable arm is connected to the galvanometer.) When an unknown gas and air are passed through the gas cell, combustion of the CO and H_2 in it at the surface of the platinum wire in this cell causes the temperature and, therefore, the resistance of this wire to increase. This change in resistance serves to unbalance the circuit and the degree of unbalance is a measure of the combustible content of the sample. The flow of gases is controlled by a system of orifices which may be changed for varying ranges of combustible content. A filter is also used ahead of the gas cell to remove solids.

Another type of analyzer which depends upon the heat of combustion is produced by Mine Safety Appliances Co. and is an adaptation of the

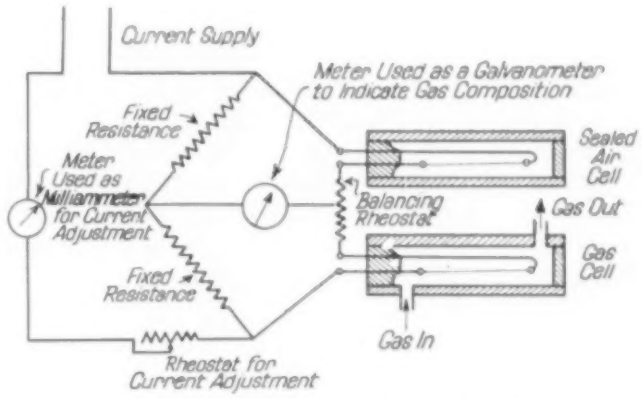


Fig. 4 — Diagram of Analyzer for Combustibles in a Gas (Bacharach Industrial Instrument Co.) Combustion along heated platinum wire in gas cell increases its temperature and its resistance, which is measured

carbon monoxide analyzer used for detecting toxic concentrations. This device measures extremely small amounts of CO, but when it is applied to furnace atmospheres its range is expanded by diluting the sample with air — a necessity for proper operation of the instrument since hydrogen and carbon dioxide are normally present in controlled atmospheres. (If CO_2 is present in concentrations of 5% or over it is adsorbed by the combustion catalyst and the consequent heat of adsorption registers as carbon monoxide. Hydrogen, also, in relatively high concentrations, is caused to burn. Since these are both concentration effects, they are eliminated or greatly reduced by diluting the sample.)

Liquid automatic flow meters are used for controlling the rate of sample and air flow and for maintaining the mixture in fixed proportion. The scale of the recording element is, of course, calibrated to read the amount of carbon monoxide in the undiluted sample. This device may use a recording potentiometer for a continuous record and can be attached to automatic control equipment.

This analyzer consists of a gas pump, a gas dryer, a gas purifier, a flow regulator and a detector cell. In operation, the CO of a conditioned

gas sample is caused to burn catalytically to CO_2 and the increase in heat content of the gas is measured. The gas pump draws the sample from the furnace and forces it, with a measured amount of air, through the remainder of the apparatus. The sample is first dried by activated alumina; the dryer is a dual unit provided with means for automatic re-activation. The gas is then passed through a charcoal tower or scrubber to remove organic vapors, and then through a flow meter and regulator for a constant rate of flow. The rate of flow depends upon the range of combustion capable of being analyzed by the instrument and is indicated by a manometer.

This conditioned and measured gas is now ready for the detector cell. This cell is mounted in a steam bath with temperature constantly at 100° C.; the sample passes through coils in the steam bath to raise it to the same temperature. The heated gas sample then flows through a bed of pumice in which the "cold" junctions of a thermopile are embedded, following which it flows through a bed of the catalyst in which the "hot" junctions of the thermopile are located. This catalyst, called "Hopcalite", is a specially prepared mixture of manganese dioxide with basic copper carbonate and is selective with respect to CO, causing it to burn to CO_2. The heat liberated increases the temperature of the catalyst, is measured by the thermopile and is proportional to the CO content. The thermopile e.m.f. may be used to actuate suitable electrical devices for indication, recording, or control.

For accuracy this device must be checked with a calibrating device which sends a known concentration of CO to the measuring instrument. The calibrator draws and measures pure CO from a cylinder, meters an air flow and mixes the two. The frequency of calibration depends upon the use; it is reported that where the instruments are used in analyzing air samples for carbon monoxide, calibration at approximately 90-day intervals is satisfactory.

Fig. 5 — General Electric Co.'s Portable Dew Point Potentiometer for Measuring the Content of Water Vapor in an Atmosphere

Another use for combustion measurement and control devices is in the calorimetric control of raw gases used for producing furnace atmospheres. This is particularly important when the supply is a fuel gas whose composition and calorific value fluctuate widely. Devices of this type are manufactured by Cutler-Hammer, Inc. and work on the principle of burning gas and air in fixed volumetric proportions and measuring the heat liberated as a temperature rise. Such temperature measurements may readily be utilized to actuate indicating, recording or control equipment. As in all devices of this type, an accurate, well-made instrument is required and it must be so designed that external conditions are eliminated or compensated. The measurement of the calorific value of a gas may be used to vary or control its flow in a predetermined manner according to the requirements of the installation. In one device of this type *all* of the combustibles in the gas are burned and the total heating value of the gas is used for control purposes. Ordinarily, the control mechanism is arranged so it will hold the product gas at a constant heating value, while a separate indicating or recording device is used to measure this heating value.

Water Content: A partial physical analysis of a controlled atmosphere is made when dew point methods are employed to determine its water content. These methods are based on the fact that when a moist gas is cooled below its saturation point or "dew point", water will precipitate. By observing the temperature at which this precipitation occurs saturation temperature is measured, and, assuming the gas behaves like air, this may be made a measure of its water content. One such meter is the "Dew Point Potentiometer" of the General Electric Co. It consists of a polished metallic mirror located in a small chamber in such a manner that it can be seen through a sight glass. The gas being tested is passed continuously through the chamber and over the metallic mirror. The temperature of the mirror is gradually lowered by directing a jet of CO_2 or some other compressed gas against its back side. When the dew-point temperature is reached a spot of dew appears on the mirror and may be observed through the

window. A light-gage thermocouple and a potentiometric balancing circuit provide a means for accurately reading the mirror temperature at the dew-point. From this temperature the water vapor in the gas may be directly determined. The range of this particular instrument (Fig. 5) is from 110 to —60° F.

Effect Determination

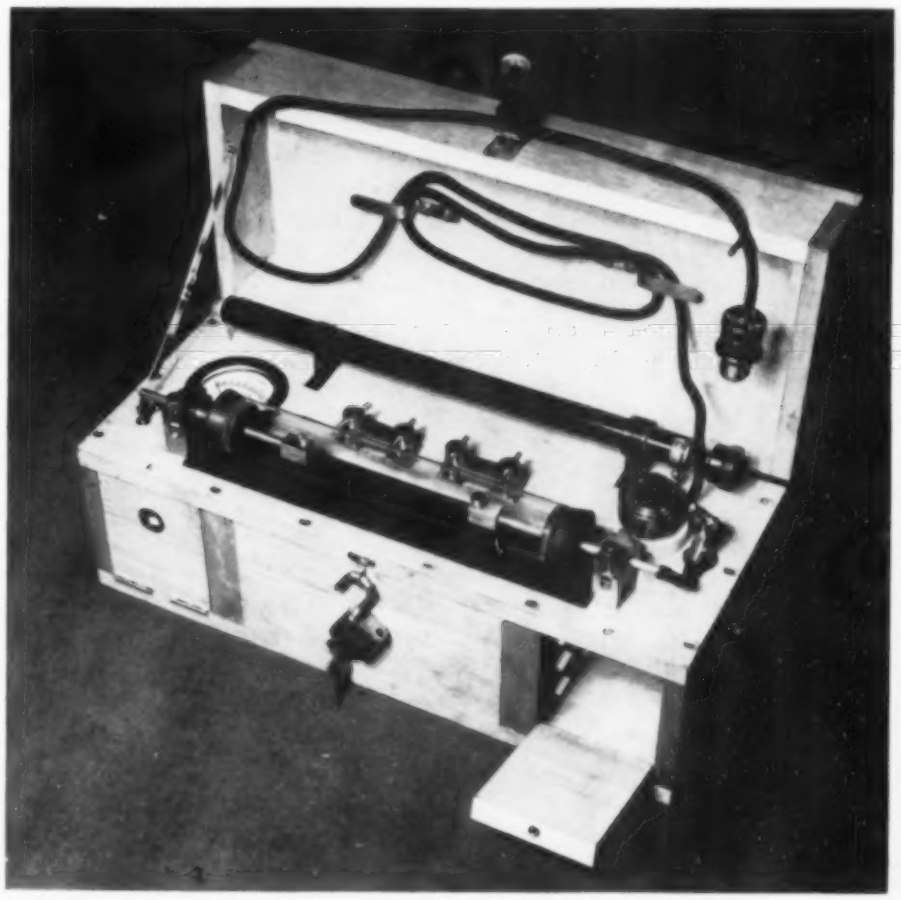
Visual Effects: A device for detecting the surface effects of controlled atmospheres on various metals which may be heat treated has been available for some time from the Electric Furnace Co. known as the "Visual Gas Tester" (Fig. 6). The test chamber is a glass tube stoppered at either end. Electrodes which pass through the stoppers are equipped with clamps by which a test strip may be fastened. Provisions are made for continuously drawing a sample of the gas being tested through this chamber. The test strip is heated by an electric current supplied by a small transformer; an ammeter measures this current and a rheostat controls its magnitude. This device can be used to test any sort of an atmosphere whose effects upon the material being heat treated can be observed by eye. This means that its most common use is for determining whether or not a given atmosphere is oxidizing, as in testing atmospheres used in bright annealing.

Carburization and decarburization are not necessarily visual; hence when used to determine these effects the instrument is used in a somewhat different manner. The tester is then used as a small-scale furnace in which a strip sample is heated under predetermined time-temperature conditions in the unknown gas and the sample later examined by microscopic, chemical or other methods. The economy of small scale tests in production work is obvious.

There are several different ways in which the instrument may be utilized but one of the more important is to determine the effect of an atmosphere upon a steel during cooling. It is well known that an atmosphere which is reducing to a steel at a high temperature may become oxidizing upon cooling, because the gas-metal equilibria with water vapor and hydrogen are such that more water vapor can be tolerated without oxidation at high temperatures than at low. To use this instrument for the purpose, as in bright annealing a low carbon steel, a low carbon steel strip say ½ in. wide and 0.01 in. thick, 6 in. long, is clamped between the electrodes and the test chamber purged until only the gas being tested is present. The whole resistance is placed in the circuit, the current turned on, and the rheostat adjusted until the ammeter reads 4 amperes (or other value which has been found suitable). By adjusting the rheostat the current is held steady for about one minute, at which time the strip has reached a temperature of 1600 to 1700° F. The current is then decreased to some predetermined lower value and held constant at that figure. As soon as the strip loses heat-color the operator starts measuring the time and notes when the strip begins to show signs of oxide discoloration (which would at first be a light straw color along the edge, then gradually become deeper in color).

The elapsed time figure is a relative measure of the reducing character of the atmosphere; the greater the time, the greater the reducing power. In a dry mixture of N_2 and CO coloration would never appear and the time would be infinite. As the oxidizing constituents of an atmosphere increase, the point can be reached where the test strip is seen to be oxidized as soon as heat color disappears and the time noted is zero. Between these two conditions there is a range in which

Fig. 6 — A Strip of Metal Is Heated Electrically in a Tube of Flowing Gas and Its Oxidizing Nature Is Observed by Tarnish or Temper Colors (Electric Furnace Co.)



atmospheres may be directly compared by this device and their performances correlated.

In addition to this comparative figure, the device directly measures the cooling rate necessary to prevent staining or oxidation. If a test strip can be cooled at a given rate in a given gas without noticeable oxidation, the work may be safely cooled at the same rate. It is also useful in finding the correct conditions for applying desired surface coloration. Straw yellow or blue coloration of steel surfaces is frequently desired for certain uses.

While the above description has dealt chiefly with the use of the visual gas tester for analyzing atmospheres for the protection of steel, it is obvious that it may be used with other metals. One such is in the bright annealing of copper, where this device is particularly useful in detecting the presence of hydrogen sulphide in the atmosphere — a very undesirable substance, even in minute amounts, because it stains the copper. The apparatus in this case is used substantially the same as previously described.

In all cases the tester is merely a small scale furnace test. For this reason, as in all atmosphere testing devices, care must be taken to see that a truly representative sample is secured and that leakage within the furnace muffle does not cause a misinterpretation of results.

Sub-Surface Effects: As far as sub-surface effects are concerned, most of the available atmosphere control instruments rely on indirect indications or measurements to evaluate changes. However, a new device for the direct indication of the effect of controlled atmospheres upon the carbon content of steels has been recently developed by Westinghouse Electric & Mfg. Co. To date this has only been used experimentally but it appears to offer considerable promise and may be developed for production use in the near future. It mounts a fine steel wire between two copper electrodes in a sealed glass tube through which a gas sample may be passed. Provision is made for heating the wire electrically and for measuring its electrical resistance when cold. The wire is heated to the same temperature (measured by the power input, or the dilation of wire) and in the same atmosphere as the work being treated. Because of its fine size this wire quickly reaches carbon equilibrium with the gas at the working temperature, after which the wire is cooled to room temperature. Since the resistivity of the wire has been determined in relation to its carbon content, it is possible to determine from a second measurement at room temperature with what carbon content a given atmosphere is in equilibrium. (Dilatometric effects may also be used as a measure of the carbon content of the wire and a projection of the wire upon a screen gives a magnification of the results.) The device must be calibrated for a given type of gas but the rate of flow does not appear to be critical.

Effects on Special Materials: Certain individual constituents in controlled atmospheres may be measured by their selective attack on special materials. In this case these materials serve the same purpose as a fuse in an electric circuit and flash a warning when unwanted changes occur.

Variations in fuel gas composition and pressure as well as variations in the temperature, humidity and density of air used in combustion invariably result in slight variations in the composition of an atmosphere produced by combustion methods. In many applications these slight variations have no effect but for some applications (such as in the nitrogen or inert gas generators, where gas and air are burned to very near the theoretical point of complete combustion and yet free oxygen cannot be tolerated) there is considerable need for an oxygen detector. In other cases small quantities of gases such as the nitrogen oxides, sulphur-containing gases, chlorine and the like must be detected in the presence of large amounts of harmless gases. An automatic device for continuously monitoring gas samples for these constituents has been developed by Continental Industrial Engineers, Inc.

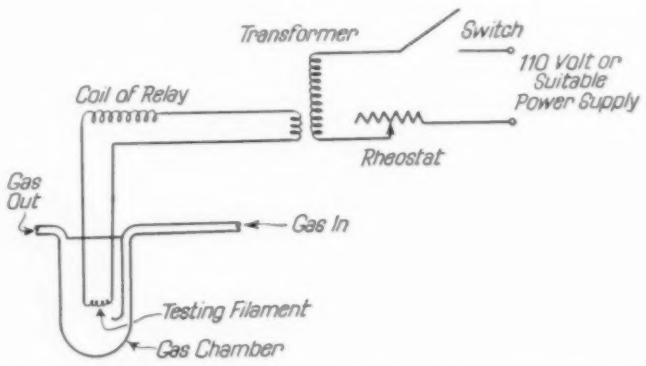


Fig. 7 — Continental Industrial Engineers' Oxygen Detector Utilizes a Hot Filament of Copper Alloy Which Burns Out Quickly When the Gas Under Test Contains Traces of Free Oxygen

This device, called an oxygen detector because of its most common use, continuously passes a sample of the gas over an electrically heated filament maintained at a constant temperature in a monitoring chamber. Various metals and alloys of differing sensitivities may be used as filaments

(Continued on page 569)

Equipment Will "Talk" In L&N's Show Exhibit

To give you the facts you want about two of our products—Homocarb Furnace and Micromax Pyrometer—they will "talk" to you in a novel presentation at the Metal Show. You may hear as much or as little as you wish; if you have a problem in parts-carburizing or in furnace control, we think you'll stay for the whole show. And, of course, we'll have engineers in attendance to answer questions about these and all other L&N products.

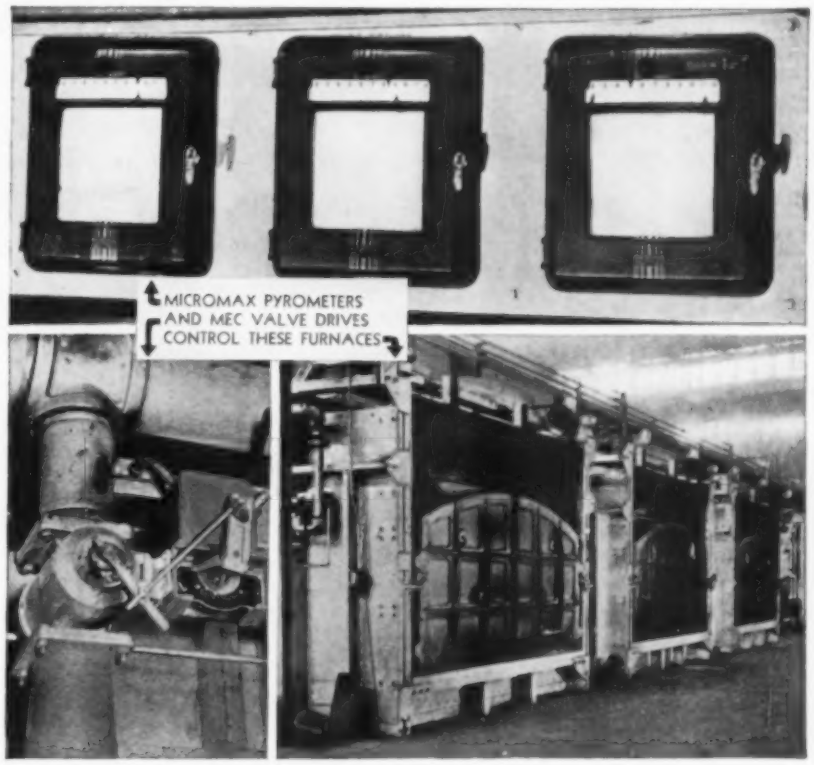
More Production From Tools & Dies When Heat-Treated This Way!

A quick, easy way to get more production from tools and dies is through complete, well-balanced heat-treatment. If the heat-treater is given accurate, dependable equipment with which to work, he may even step up the useful life of the very next tool he heat-treats. And, if his equipment is for Vapocarb-Hump hardening and Homo tempering, he need never do less well on any future tool—he is, in fact, almost sure to do even better, until the maximum is reached. Our files are full of such cases . . . we should greatly like to put you in touch with some user who has had such experience and who may be willing to place it at your disposal.

Vapocarb hardens all steels except high-speed. Homo tempers at any heat up to 1450, sometimes to 1500 F. The equipments are complete in every respect; factory-assembled as far as possible, with control panels wired, ready to use when you get them.

Typical arrangement of Vapocarb-Hump hardening furnace, tool-type Homo tempering furnace, with their control panels and the quench tank, all arranged so heat-treater can rapidly and accurately apply his skill to production of longer-lived tools

For brief descriptions, see Broadside T. Or ask for specific, detailed literature.



Annealing IS EASIER

When Micromax Pyrometers Control Furnaces

Being able to set their furnace controllers and then forget them is one of the production-increasing conditions enjoyed by the operators of the heat-treat shown here.

This company produces cast and forged specialties, which require high-quality heat-treatment. Excellent furnace-temperature control is thus more than just something to aim at—it's essential to trouble-free production. And, to get it, they simply set one knob on a furnace's Controller. Even the sudden changes in outside weather, fuel pressure, etc., are then automatically compensated for, so that they don't affect the temperature. The Control operates continuously, at full dependability, day and night, assuring everyone concerned that annealing and malleableizing heats are to specification.

Easy, Neat Way To Prepare Pyrometer Charts For Filing

To get the full good out of a recording pyrometer, it is often necessary to maintain a file of its charts, and we now have available an arrangement which greatly helps in preparing strip-charts for such a file.

This equipment permits the user of a Micromax strip-chart instrument to tear off a piece of its chart whenever desired, without wasting chart and without having to thread the chart back through its guides. Included can be a rubber-stamp, identification of the recorder or the location of thermocouples.

This equipment thus provides daily records, as convenient as those of the round-chart Micromax yet with the greater detail and multipoint features of the strip-chart. Any L&N salesman can explain this tear-off feature.

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LEEDS & NORTHRUP COMPANY, 4927 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS • TELEMETERS • AUTOMATIC CONTROLS • HEAT-TREATING FURNACES

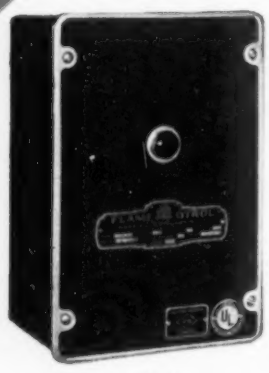
MOBILIZING

Wheelco's entry into the instrument industry proved revolutionary. New principles and new standards of temperature measurement and control were introduced. Anticipating industry's future needs, engineering skill and foresight were mobilized to incorporate these principles in a wide range of instruments.

Capacitrols

1935
"Radio Principle" Control

The "Radio Principle" electronic control was introduced in 1935 and has since thoroly proved its superiority over all other type controllers. "Limitrols" and an initial line of Indicating Pyrometers were also introduced.



Flame-otrols

1936
"Flame-otrols"

The "Flame-otrol", announced in 1936, is the only combustion safeguard for all fuels approved by both Underwriters Laboratories and Factory Mutual Laboratories. A complete line of Portable Indicating Pyrometers was added to supplement other Wheelco equipment.

1937
"Proportioning Control"

Wheelco made instrument history again in 1937 with the announcement of the "Proportioning Control" as a means of continuously varying fuel input to maintain constant temperature—available with all "Radio Principle" Controllers. Other important additions included Portable Potentiometers, "Heat-eyes" and Time Delay Relays.

1938
"Potentio-trols"

A major step in the rapid growth of the Wheelco Instruments Company was the perfection of a Potentiometer Controller — "Potentio-trol" — combining the extreme sensitivity of "Radio Principle" Control with the proved accuracy of the potentiometric method of temperature measurement. A "Program Control", applicable to all "Radio Principle" Controllers, was introduced together with "Rheotrols", "Flame-eyes" and Automatic Ignition "Flame-otrols."

Potentio-trols

1939
Thermometers

In 1939 Wheelco broadened its line to include Thermometers. The acclaimed sensitivity of "Radio Principle" Control was combined with Indicating Thermometers for low temperature applications. Besides Control Thermometers, Wheelco also presented Indicating and Recording Thermometers. Electric Valves, employing an electrothermal expansion principle, became an important addition.

Wheelco Instruments Co.

1929-33 S. HALSTED STREET • • • CHICAGO, ILLINOIS

Analytical Methods

(Continued from page 552)

standards as a rule must be based on chemical analysis, except for the determination of very minor percentages of elements. More and more calls are coming in for standard alloy samples but few, except those who have cooperated in analyzing the Bureau of Standards' samples, have any conception of the thought, skill and high cost ("high" in comparison with costs of ordinary routine analyses) involved in either the preparation or the analysis. Only a concerted effort, subsidized by industry, appears able to supply the proper number of standard samples.

During the year A.S.T.M. Committee E-2 on Spectrographic Analysis organized and held a symposium at Atlantic City in which an attempt was made to correlate the desires of the engineer and metallurgist as to precision with the efforts and abilities of the spectroscopist. A main purpose was to encourage more factual thinking, discussion and self appraisal.

The literature has been filled to confusion with schematic diagrams of novel, not so novel, and pet spark hook-ups, but now — thanks to growing competition among instrument manufacturers — new built-up circuits are becoming available. So too are new designs in densitometers, comparators, and other accessories. Demands continue for improved electrodes, though good graphitized carbons are available (high-purity carbons are being made so) and for better plates. Photographic technique is being properly stressed.

Massachusetts Institute of Technology held its usual worth-while and well attended conference, and the University of Chicago its first. At the M.I.T. conference a Society of Applied Spectroscopy was tentatively organized and decision was made to publish the proceedings of the society and the conference in either the *Journal* of The Optical Society of America or in a tentatively planned Journal of Applied Spectroscopy to be issued quarterly. Officers of the society headed by Prof. GEORGE R. HARRISON were elected.

This is a development to be watched.

More colleges are initiating courses in spectrography. It is hoped that they will stress the fundamental foundations rather than dissipate their energies in mere teaching of laboratory skills (which can come with the first job in industry) or one or two special methods. If the schools will only correlate the role of the physicist with that of the analytical chemist, spectrography will progress more efficiently. The spectrograph still remains a tool of the analytical chemist, but no one should ignore the part that the physicist or physical chemist must play in developing it.

Page 568

Control of Atmospheres

(Continued from page 566)

for the selective detection of a range of gases over a range of compositions. For oxygen detection the filament must be made of a metal which is inert in the presence of CO_2, H_2O, N_2, CO, H_2, and CH_4, but which is extremely sensitive to traces of oxygen and when exposed to these traces will burn through, thereby actuating a suitable relay and alarm. A copper alloy meets these requirements satisfactorily. When burned out this filament may be readily replaced and the device is again ready for use. A sketch of such a device is shown in Fig. 7 on page 566; connections with a red warning lamp, which lights when the testing filament burns out, are made through the relay, but not indicated on the sketch.

Conclusions

From the above it will be seen that manual equipment is available for the complete chemical analysis of a controlled atmosphere, but this equipment is not satisfactory for the usual metallurgical application in production because of the skill required in operating it and the time required for a complete analysis. Rapid-acting recording and control equipment is available for determining specific properties of controlled atmospheres. This equipment is well engineered and may be adapted to practically any type of controlled atmosphere, but the user must carefully determine the requirements of his installation as no instrument now available is universally applicable.

Where unusual or new conditions are encountered, a chemical analysis of a controlled atmosphere is practically essential except in those cases where the effect of the atmosphere upon a sample can be directly observed. Once an installation is stabilized, other types of atmosphere measurement may be entirely satisfactory to keep it stabilized. While equipment to secure almost any desired result is now available, there appears to be a considerable need for a simplified and cheaper device for special furnace atmosphere control. The continuous user of controlled atmospheres in a large way can easily afford to invest $500 in an excellent atmosphere controller or recorder for his plant, but the intermittent user of controlled atmospheres frequently cannot justify such an investment. Now that suitable equipment is available for the large user the next step appears to be the development of a cheap apparatus for the small user. Some of the instrument producing companies are definitely interested in such a device and it may be expected that it may eventually be developed to the commercial stage.

for INDUSTRY'S NEEDS

For the past five years Wheelco has provided the ultimate in Indicating and Controlling temperature instruments. Mobilizing past experience with an understanding of industry's future needs - Wheelco continues to pioneer.

1940
"Therm-otrols"

Recording Therm-otrol

Today, Wheelco offers the "Therm-otrol" to set a new standard for Recording Control Thermometers. The "Therm-otrol" is adaptable to every application. It is available for ranges between 0° F. to 1000° F., as: (1) an Indicating Thermometer; (2) an Indicating Controller; (3) an Indicating Controller, with "Flame-otrol"; (4) a Recording Thermometer; (5) a Recording Controller; (6) a Recording Controller, with "Flame-otrol". More than sixty-five individual models of this instrument are available.

Wheelco is proud of its revolutionary achievements in its initial five years of existence and of its proved versatility in anticipating industry's ever changing and exacting requirements.

For further information on Wheelco instruments, write for general catalog G2000-5, which illustrates entire line.

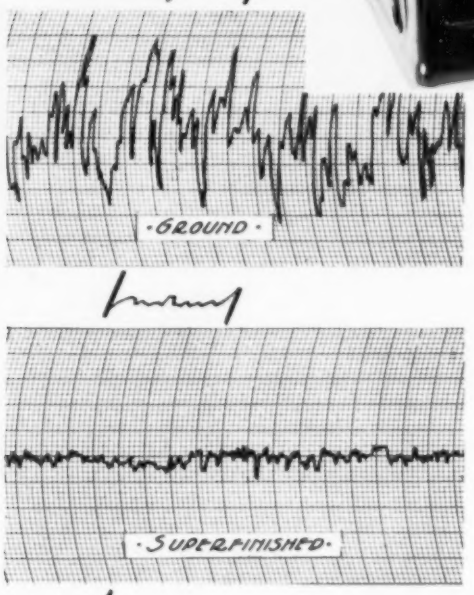
Wheelco Instruments Co.
1929-33 S. HALSTED STREET • • • CHICAGO, ILLI

The BRUSH SURFACE ANALYZER

accurate

simple

fast



"Topographic" Profile of finished surfaces .... actual height above and depth below mean reference level in **Millionths** of an **Inch** in finished metals, glass, plastics, paper, etc.

Immediate and **Permanent** ink-on-paper record.

Tracer method of recording . . . surface under test explored by fine sapphire point the vertical motion of which is amplified up to 60,000 times in the corresponding pen motion on moving paper chart.

Utmost Simplicity of operation . . . readily set up in shop or laboratory for production or research by simply plugging into 110 volt 60 cycle power supply.

Portable and **Rugged** . . . easily transportable in carrying cases in which instrument may be operated.

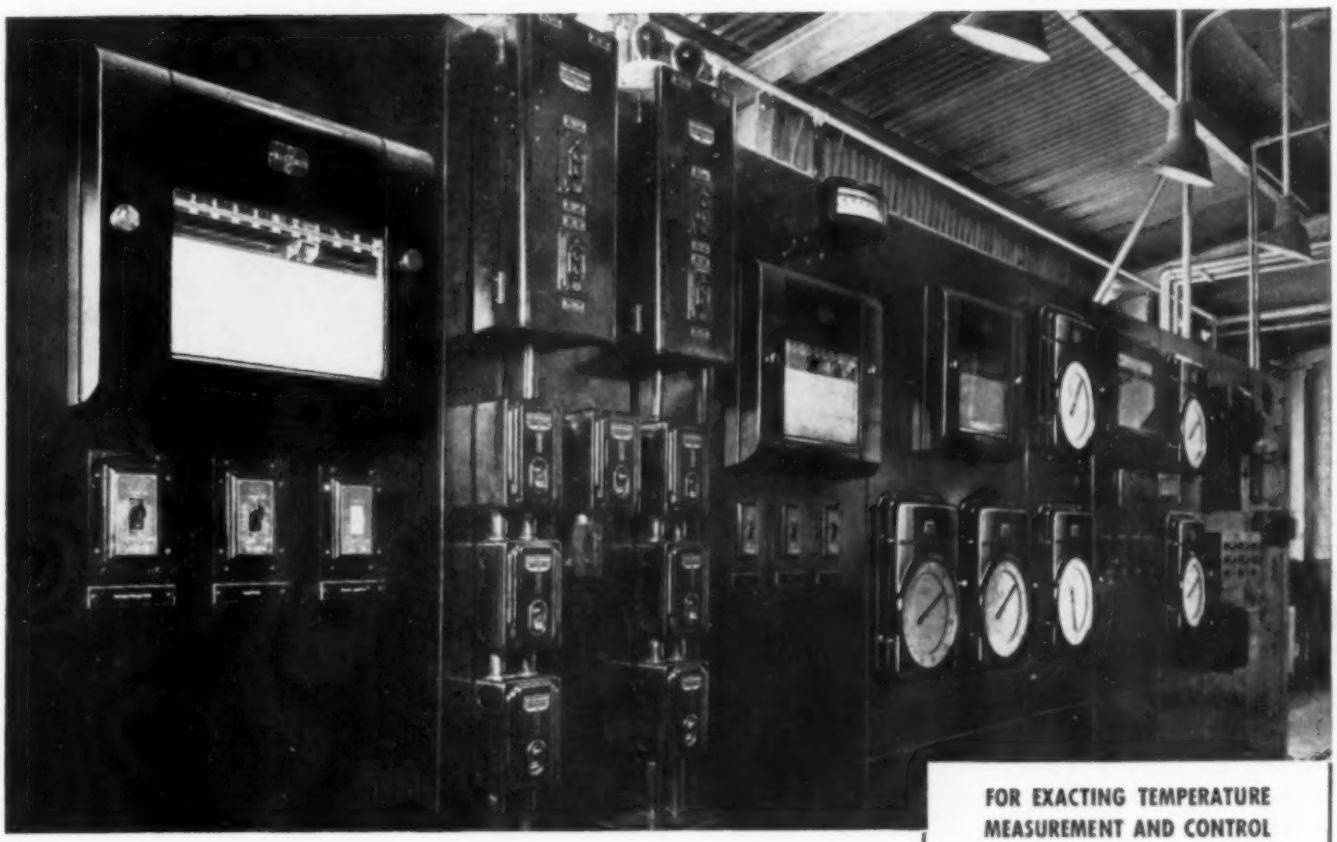
Booth No. Z-235 at National Metal Exposition

THE BRUSH DEVELOPMENT CO.
3311 PERKINS AVENUE • • • • CLEVELAND, OHIO

HERE ALSO

IT'S BRISTOL'S CONTROL

FOR BRIGHT-ANNEALING FURNACES!



In order to protect the quality of its stainless steel sheets, this steel plant in the Pittsburgh district controls the temperatures of bright-annealing furnaces with precision accuracy by means of Bristol's Strip-Chart Potentiometer Pyrometer Controllers and Bristol's Indicating Dial Type Pyromaster Potentiometer Controllers. In addition, both Bristol's Strip-Chart Pyrometers and Bristol's Pyromasters are installed for continuously recording the temperatures in important zones in the four furnaces which they serve.

BRISTOL'S

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THE BRISTOL COMPANY
WATERBURY, CONNECTICUT

Branch Offices: Akron, Birmingham, Boston, Chicago, Detroit, Los Angeles, New York, Philadelphia, Pittsburgh, St. Louis, San Francisco, Seattle. Canada: The Bristol Company of Canada, Limited, Toronto, Ontario. England: Bristol's Instrument Company, Limited, London, N.W. 10

FOR EXACTING TEMPERATURE MEASUREMENT AND CONTROL

Bristol's Potentiometer Pyrometers offer many advantages, as follows:

INDICATING PYROMASTER POTENTIOMETER PYROMETER

Unaffected by vibration. Rugged galvanometer. Moving parts operate only when the temperature changes. Automatic cold junction compensator. Extreme accuracy. Ask for Bulletin 507H.

STRIP-CHART POTENTIOMETER PYROMETER

Extra wide 12¼" chart. Large, easy-to-read scale. Automatic standardization. Automatic cold junction compensator. Extreme accuracy. Ask for Catalog 1452H.

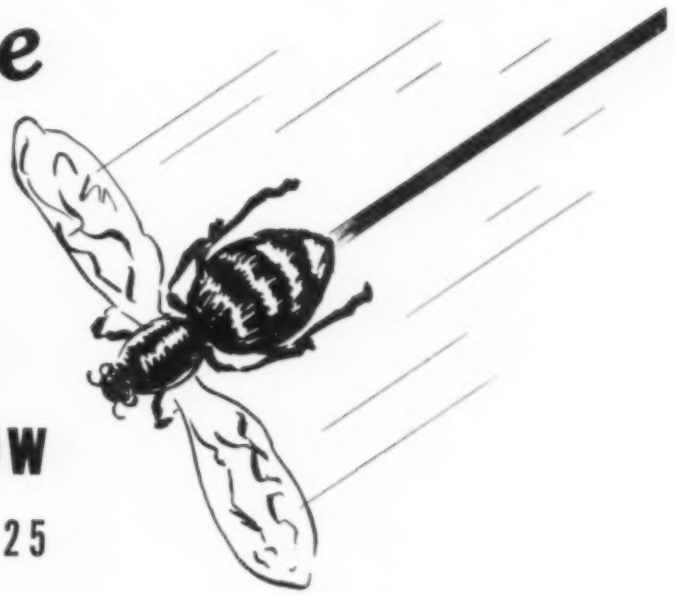
"ROCKWELL"
HARDNESS TESTER

Whoever enters your shop and sees one of these testers knows you are striving to do good and conscientious work, for the reliability of these testers is widely appreciated.

WILSON
MECHANICAL INSTRUMENT CO., INC.
Concord Avenue, N. Y. City

IF YOU ARE INTERESTED IN METALLURGICAL TESTING

Make a bee line



FOR

BOOTH Y-20

NATIONAL METAL SHOW

CLEVELAND OCTOBER 21-25

The very latest in laboratory equipment . . . apparatus that will speed up your production and give you unmistakable determinations . . . will be on display and in operation at the Buehler Booth in Cleveland during the 1940 National Metal Exposition.

Drop in and look over these instruments and get a new idea about the use of concise metallurgical testing equipment. They indicate why Buehler is a respected name in metallurgical laboratories all over the country. If you don't get an opportunity to see the Buehler Exhibit at the Metal Exposition, write today for "THE METAL ANALYST", which gives complete details about the AB line.

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THE METAL ANALYST

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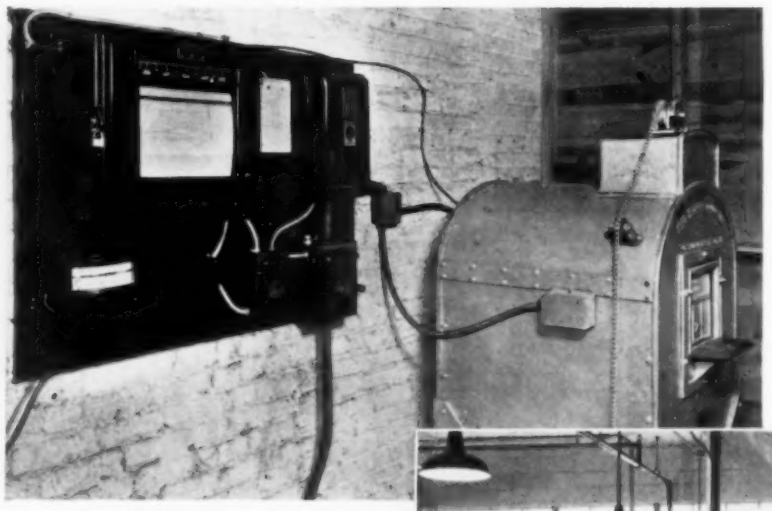
UNMISTAKABLE

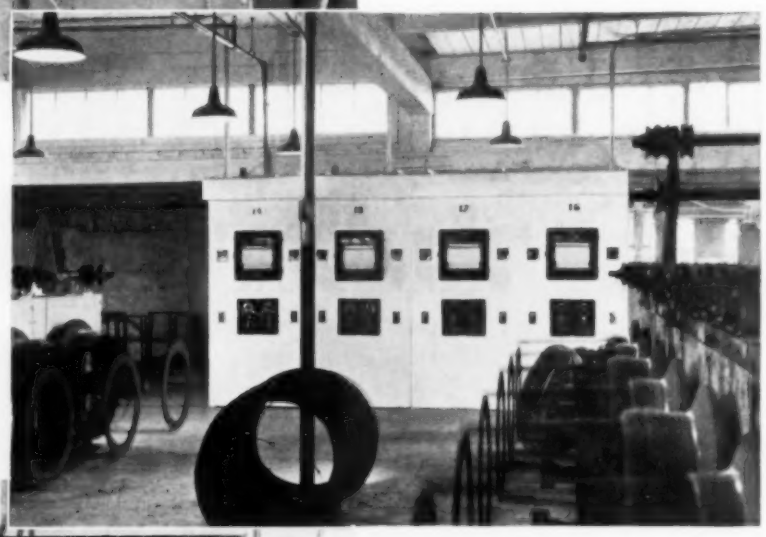
DETERMINATIONS

See for yourself



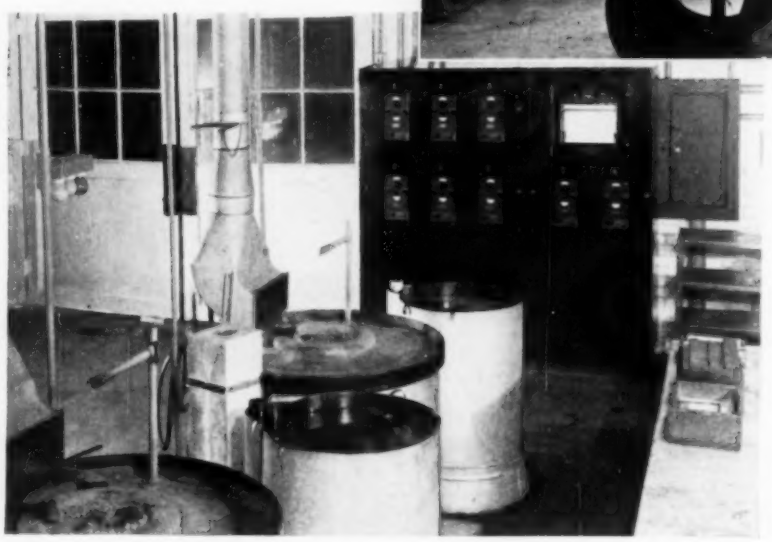
• Even in this plant employing but a single furnace, the Foxboro Potentiometer Recorder-Controller shown here brings important economies. Its exact control of heat treating practically eliminates costly tool breakage.

• • •



• This bank of Foxboro Potentiometer Recorders and Controllers is responsible for unusual uniformity in the products of a large wire manufacturer. The slightest temperature deviation in patenting furnaces is promptly corrected and recorded.

• • •



• Smooth, close control of heat treating . . . with continuous accurate records . . . is obtained in a leading small-tool plant, through this centralized panel equipped with a Foxboro Potentiometer Recorder and Foxboro Potentiometer Controllers.

• • •

Furnaces and Refractories

Blast Furnace Construction and Operation

By Wm. A. Haven
Vice-President, Arthur G. McKee & Co.

THE MOST NOTABLE improvements during the past year, we believe, have been in the direction of improving uniformity of furnace operations. Blending of ores by bedding, and application of modern "air conditioning" methods to remove excessive moisture from the blast, are outstanding examples. These have been fully described several times in the technical magazines.

In furnace dimensions there is a pronounced tendency toward higher stacks, but it is somewhat too early to say whether this will reduce manufacturing costs to a greater extent than those that have followed other means of increasing the total volume of the furnaces, such as increasing hearth and top diameters. Correct distribution of the stock below the bells in the very large furnaces remains something of a problem.

This year will see the first all-welded furnace shell. Value of this type of fabrication as compared with riveting will therefore in some degree soon be determined.

Improvement of various auxiliary equipment, gas washers, hot blast stoves, gas burners and the like continues but nothing of a radical change in these respects is to be noted. In the majority of furnaces being built or rebuilt this year, double compartment type of cooling plates have been adopted to prevent failure of cooling protection to the furnace lining above the mantle.

Some very interesting work in material preparation is to be noted in the successful beneficiation by sintering of carbonate ores by the Algoma Steel Corp. and a commercial size plant for concentration of southern ores by the Republic Steel Corp., now under construction. More intensive exploitation of the magnetite ores from New York State — long mined in rather moderate quantities — marks an interesting trend in the utilization of American resources.

Special Refractories

By Gilbert E. Seil
Technical Director, E. J. Lavino & Co.

A SURVEY of the patent literature and of commercial production indicates a tendency to an effort to substitute for basic refractories products made from dolomite, heat treated with or without one or more of the following reacting substances: Silica, alumina, iron oxide, manganese oxide, phosphoric acid, boric acid, chromite, clay and similar materials. Although most of the efforts in this direction are haphazard, they are fundamentally sound scientifically and there is reason to assume that real progress is being made in this field.

The refractories offered to the consumer up to the present time are not to be used as a measure as to what is to be offered in the future. Before the materials can be substituted for chrome and magnesia refractories, intensive, careful, scientific research must be completed, and planned field tests made to determine the value of the products.

Dolomite is one of the most abundant and

Properties of Refractory Materials, Except Fireclay

Compiled by Stuart M. Phelps, and Copyrighted 1935 by American Refractories Institute, Technical Dept., Mellon Institute.

Material (1)	Composition of the Pure Material		Melting Point	True Specific Gravity	Hardness (Moh's Scale)	Mean Specific Heat (17)	Thermal Expansion (Note 22)	Thermal Conductivity (2)		
	Formula	Composition %						At 1000°F.	At 1600°F.	At 2400°F.
Andalusite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810°C. 3290°F.	3.20	7.5	0.168 (18)	6.2*			
Chromite	$FeO.Cr_2O_3$ (3)	Cr_2O_3 68 FeO 32	2180°C. 3956°F.	4.5	5.5	0.22*	8.0*	10.0*	10.9*	12.1*
Corundum	Al_2O_3	Al_2O_3 100	2050°C. 3722°F.	4.0 (24)	9	0.304*	8.5	23.0*	26.5*	30.0*
Cyanite (Kyanite)	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810°C. 3290°F.	3.6±	4 to 7		4.9* (4)			
Diasporite (Diaspore) (5)	$Al_2O_3.H_2O$	Al_2O_3 85.1 H_2O 14.9	2050°C. 3722°F.	3.4 to 3.5	6.5 to 7	(Note 6)	6.5*			
Dolomite	$CaCO_3.MgCO_3$	CaO 30.4 MgO 21.9 CO_2 47.7	(Note 23)	2.81 to 2.95	3.5 to 4.0	0.222 (19)	14.0			
Dumortierite	$8Al_2O_3.6SiO_2.B_2O_3.H_2O$	SiO_2 64.6 Al_2O_3 28.5 B_2O_3 5.5 H_2O 1.4	1810°C. 3290°F.	3.30	7		5.2*			
Forsterite	$2MgO.SiO_2$	MgO 57.3 SiO_2 42.7	1910°C. 3470°F.	3.22	6 to 7	0.22 (19)	10.5*	11.1*	10.6*	10.3*
Graphite	C	C 100	>3000°C. >5432°F.	2.25	1 to 2	0.29	2.2			
Magnesia spinel	$MgO.Al_2O_3$	MgO 28.2 Al_2O_3 71.8	2135°C. 3875°F.	3.6	8	0.257	8.5	12.2*	13.3*	14.5*
Mullite	$3Al_2O_3.2SiO_2$	Al_2O_3 71.8 SiO_2 28.2	1810°C. 3290°F.	3.03		0.175 (20)	5.3 (7)			
Periclase (Magnesia) (8)	MgO	MgO 100	2800°C. 5072°F.	3.64 to 3.67	5.5 to 6.0	0.285	13.5*	19.5*	15.5*	13.0*
Quartz (9) (Quartzite)	SiO_2	Silica 100	1400°C. (10) 2552°F.	2.653	7	0.263*	32.6* (11) 4.6 (12)	8.8*	10.7*	13.3*
Silicon carbide	SiC	Si 70 C 30	2250°C. (13) 4082°F.	3.17 to 3.21	9 to 10	0.19 (14)	5.2 (15)	142*	110*	80*
Sillimanite	$Al_2O_3.SiO_2$	Al_2O_3 62.85 SiO_2 37.15	1810°C. 3290°F.	3.24	6.5 to 7.5	0.175				
Zircon (Zirconium silicate)	$ZrO_2.SiO_2$	ZrO_2 67.1 SiO_2 32.9	2550°C. 4622°F.	4.7	7.5	0.132 (21)	4.5			
Zirconia (Zirconium oxide)	ZrO_2	Zr 73.9 O_2 26.1	2700°C. 4892°F.	5.5 to 6.0	6.5	0.16	6.6 (16)	12.0*	13.0*	14.0*

*1. These properties refer to pure materials and not to commercial refractories which may differ because of impurities, bonding materials, and process of manufacture. The specific heat, thermal expansion and thermal conductivity data, however, may be used for engineering purposes and especially those marked with asterisk (*) which were obtained from commercial products.

2. Thermal conductivity in B.t.u. per in., per hr., per sq.ft., per °F., averaged from the more reliable data on refractories.

3. General chemical formula for chromite is $RO \cdot R_2O_3$. The RO oxide is usually FeO and may be replaced in part by MgO, while the R_2O_3 is mostly Cr_2O_3, but may be replaced in part by Al_2O_3 and Fe_2O_3.

4. Indian.

5. Commercial diaspore is composed of diasporite grains bonded with clay.

6. Probably close to 0.26.

7. Synthetic, pure.

8. Magnesite is amorphous, or crystalline like periclase, depending upon the heat treatment it has received.

9. Ganister is the commercial form for use in refractories, about 98% silica.

10. Crystobalite is the stable form of silica above 1470° C., and has the melting point of 1713° C. (3115° F.).

11. Value is for silica brick, mean expansion in range 20 to 300° C.

12. Value is for quartz, mean expansion in range 300 to 1135° C.

13. Dissociation temperature; oxidation may begin at 900° C. (1652° F.).

14. Varies with temperature.

15. This figure, and those for thermal conductivity, are for recrystallized material.

16. Pure material sintered.

17. For the range 20 to 1000° C. (68 to 1832° F.) unless noted.

18. For the range 0 to 100° C.

19. For the range 20 to 100° C.

20. For the range 20 to 800° C.

21. For the range 21 to 51° C.

22. Values for the mean reversible thermal expansion per ° C. times 10^6, for the range 20 to 1000° C. unless noted.

23. Dissociates at very high temperatures.

24. Alpha modification.

common minerals in the United States. Olivine is another possible source of substitution for basic refractories. Several reports on service tests on this material have been received, and vary to both extremes. However, for certain services olivine mixed with magnesia or with magnesia and chrome ore seems to hold some promise.

The tendency in the metallurgical industry is toward higher temperatures, therefore the refractories of the future must have properties and characteristics which differ substantially from those of most of our present ones, and will require the preparation of the materials from which they are made in such a manner that chemical rearrangement and physical changes will not take place in the finished bodies within the temperature range of the service to which they are to be subjected.

Already many changes in the method of manufacture of special refractories have contributed materially to their value in service. Methods of grinding which yield proper particle shape and proper surface condition have been developed, and methods of sizing are used to produce more uniform porosity, particularly in respect to pore size, pore shape and pore distribution. Tempering has been studied, and many refinements have been made which tend toward increased uniformity. Segregation is being studied and various methods are being found to prevent it.

Dry pressing is advancing rapidly after a lull of 40 years. We now have de-airing, mold lubrication, internal lubrication, various pressing cycles, higher pressures, bigger presses and much better control of wetting fluids.

Manufacture of brick is man's oldest profession. After many generations of inactivity the art is actively advancing and we can look forward toward real progress both in raw materials and in methods of manufacture.

Basic Refractories

By Harley C. Lee
Director of Research, Basic Dolomite, Inc.

AN INCREASED TEMPO of metallurgical operations is resulting in an increased consumption and use of basic refractories — due in part to increased steel production, in part to the demand for greater furnace output, but more particularly to improvements in basic refractories, to new applications of these refractories, and to better ways of installing and repairing them. When furnaces are pushed to capacity, the increased furnace throughput is usually gained by a greater heat input or more efficient use of that heat. This usually results in higher furnace temperatures and an increased burden on the refractories. During periods of peak production, furnaces can less easily be taken off for rebuild or repairing, and under such conditions basic refractories are doing yeoman service in increasing the life of critical parts of the furnace.

The development of new, high quality refractories takes place slowly. Good refractories require long use under observation to prove their merit. Such service tests are usually followed by gradual improvement in the refractory, and finally the adaptation of the product to new applications.

Advancing trends in basic refractories are notable in the development and application of unburned magnesia brick and chrome-magnesia brick for the construction and maintenance of metallurgical furnaces. The application of unburned brick has been particularly noteworthy in the copper and steel industries.

Unburned basic brick are in use in copper smelters for reverberatory furnace linings and roofs; in anode furnace linings and roofs; and to a lesser extent in converter linings. They have been successfully used for suspended roofs in large reverberatory furnaces. Some such furnaces have a complete roof of this sort; others use a suspended basic roof near the firing end of the furnace. *(Continued on page 600)*

Combustion of Common Gases

Adapted (by permission) from tables in 1938 issue of American Gas Catalog and Handbook

Material, Formula and Reaction	Molecular Weight	Specific Gravity (Air = 1.0)	Density at 60° F., 30 In. Barometer		Specific Heat (H_2O = 1.0)	Heat of Combustion				Cu.Ft. per Cu.Ft. Combustible				
			Lb./Cu.Ft.	Cu.Ft./Lb.		B.t.u. per Cu.Ft.		B.t.u. per Lb.		Required for Combustion		Products of Combustion in Air		
						Gross	Net	Gross	Net	Air	O_2	CO_2	H_2O	N_2
Carbon, C (to CO) ..... $C+\frac{1}{2}O_2=CO$	12.010	.....	.....	.....	....	.....	.....	4,001	4,001	2.382*	0.5*	1.0* CO	...	1.882*
Carbon, C (to CO_2) ..... $C+O_2=CO_2$	12.010	.....	.....	.....	....	.....	.....	14,136	14,136	4.764*	1.0*	1.0*	...	3.764*
Carbon monoxide, CO ..... $CO+\frac{1}{2}O_2=CO_2$	28.010	0.9667	0.07402	13.509	0.243	321.7	321.7	4,346	4,346	2.382	0.5	1.0	...	1.882
Carbon dioxide, CO_2	44.010	1.5289	0.11707	8.542	0.203	.....	.....	.....	.....	.....	...	...	...	.....
Hydrogen, H_2 ..... $H_2+\frac{1}{2}O_2=H_2O$	2.0162	0.06951	0.005323	187.881	3.409	325.0	274.6	61,061	51,592	2.382	0.5	...	1.0	1.882
Paraffin Series, C_nH_{2n+2}														
Methane, CH_4 ..... $CH_4+2O_2=CO_2+2H_2O$	16.042	0.5548	0.04248	23.542	0.593	1,015.0	914.0	23,896	21,517	9.528	2.0	1.0	2.0	7.528
Ethane, C_2H_6 ..... $C_2H_6+3\frac{1}{2}O_2=2CO_2+3H_2O$	30.069	1.0468	0.08016	12.475	0.397	1,790	1,637	22,330	20,422	16.674	3.5	2.0	3.0	13.174
Propane, C_3H_8 ..... $C_3H_8+5O_2=3CO_2+4H_2O$	44.095	1.550	0.11866	8.427	0.365	2,572	2,366	21,675	19,939	23.820	5.0	3.0	4.0	18.820
n-Butane, C_4H_{10} ..... $C_4H_{10}+6\frac{1}{2}O_2=4CO_2+5H_2O$	58.121	2.078	0.1591	6.284	0.351	3,393	3,132	21,321	19,681	30.966	6.5	4.0	5.0	24.466
Iso-Butane, C_4H_{10} ..... $C_4H_{10}+6\frac{1}{2}O_2=4CO_2+5H_2O$	58.121	2.066	0.15815	6.323	0.351	3,364	3,105	21,271	19,633	30.966	6.5	4.0	5.0	24.466
n-Pentane, C_5H_{12} ..... $C_5H_{12}+8O_2=5CO_2+6H_2O$	72.147	2.49*	0.1907*	5.245*	....	4,023*	3,720*	21,101	19,511	38.112*	8.0*	5.0	6.0	30.112
n-Hexane, C_6H_{14} ..... $C_6H_{14}+9\frac{1}{2}O_2=6CO_2+7H_2O$	86.173	2.97*	0.2277*	4.392*	....	4,771*	4,418*	20,954	19,404	45.258*	9.5*	6.0	7.0	35.758
Olefin Series, C_nH_{2n}														
Ethylene, C_2H_4 ..... $C_2H_4+3O_2=2CO_2+2H_2O$	28.052	0.9747	0.07464	13.398	0.363	1,615	1,514	21,638	20,285	14.292	3.0	2.0	2.0	11.292
Propylene, C_3H_6 ..... $C_3H_6+4\frac{1}{2}O_2=3CO_2+3H_2O$	42.079	1.481	0.11340	8.819	....	2,380	2,226	20,990	19,630	21.438	4.5	3.0	3.0	16.938
Butylene, C_4H_8 ..... $C_4H_8+6O_2=4CO_2+4H_2O$	56.105	1.935	0.1482	6.750	....	3,079	2,877	20,780	19,420	28.584	6.0	4.0	4.0	22.584
Aromatic Series,														
Benzene, C_6H_6 ..... $C_6H_6+7\frac{1}{2}O_2=6CO_2+3H_2O$	78.109	2.712*	0.2076*	4.816*	....	3,758*	3,607*	18,100(*a*)	17,370(*a*)	35.730*	7.5*	6.0	3.0	28.230
Toluene, C_7H_8 ..... $C_7H_8+9O_2=7CO_2+4H_2O$	92.135	3.177*	0.2433*	4.110*	....	4,452*	4,250*	18,300(*a*)	17,470(*a*)	42.876*	9.0*	7.0	4.0	33.876
Xylene, C_8H_{10} ..... $C_8H_{10}+10\frac{1}{2}O_2=8CO_2+5H_2O$	106.161	3.661*	0.2803*	3.567*	....	5,189*	4,937*	18,510(*a*)	17,610(*a*)	50.022*	10.5*	8.0	5.0	39.522
Acetylene, C_2H_2 ..... $C_2H_2+2\frac{1}{2}O_2=2CO_2+H_2O$	26.036	0.907	0.06946	14.396	0.383	1,491	1,440	21,460	20,730	11.910	2.5	2.0	1.0	9.410
Naphthalene, $C_{10}H_8$ ..... $C_{10}H_8+12O_2=10CO_2+4H_2O$	128.165	.....	.....	.....	....	.....	.....	17,314(*b*)	16,718(*b*)	57.168*	12.0*	10.0	4.0	45.168
Ammonia, NH_3 ..... $NH_3+\frac{3}{4}O_2=\frac{1}{2}N_2+1\frac{1}{2}H_2O$	17.032	0.5966	0.04568	21.890	0.520	442	365	9,678	8,000	3.573	0.75	...	1.5	3.323
Nitrous oxide, N_2O	44.016	1.530	0.11712	8.538	0.221	.....	.....	.....	.....	....	...	...	...	.....
Nitric oxide, NO	30.008	1.0365	0.07936	12.600	0.232	.....	.....	.....	.....	....	...	...	...	.....
Hydrogen sulphide, H_2S ..... $H_2S+1\frac{1}{2}O_2=SO_2+H_2O$	34.076	1.1902	0.09114	10.973	0.245	637	586	6,992	6,432	7.146	1.5	1.0 SO_2	1.0	5.646
Sulphur dioxide, SO_2	64.060	2.2636	0.17333	5.769	0.154	.....	.....	.....	.....	....	...	...	...	.....
Water vapor, H_2O	18.016	0.6220*	0.04763*	20.995*	0.48	.....	.....	.....	.....	....	...	...	...	.....
Oxygen, O_2	32.0000	1.1051	0.08462	11.818	0.217	.....	.....	.....	.....	....	...	...	...	.....
Nitrogen, N_2	28.016	0.9671	0.07405	13.504	0.244	.....	.....	.....	.....	....	...	...	...	.....
Nitrogen ("Atmospheric") (*c*)	28.161	0.9721	0.07443	13.435	0.242	.....	.....	.....	.....	....	...	...	...	.....
Air (*d*)	.....	1.0000	0.07657	13.060	0.2375	.....	.....	.....	.....	....	...	...	...	.....

Typical Commercial Gases

Kind of Gas	Constituents of Gas—Per Cent by Volume								Heat of Combustion								Cu.Ft. per Cu.Ft. Combustible				
	CO_2	Ill.	O_2	CO	CH_4	C_2H_6	H_2	N_2	B.t.u. per Cu.Ft.		B.t.u. per Lb.		Specific Gravity (Air = 1.0)	Density at 60° F., 30 In. Barometer		Specific Heat (H_2O = 1.0)	Required for Combustion		Products of Combustion in Air		
									Gross	Net	Gross	Net		Lb./Cu.Ft.	Cu.Ft./Lb.		Air	O_2	CO_2	H_2O	N_2
Natural gas																					
Mid-Continent	0.8	...	...	...	96.0	...	...	3.2	974	877	22,122	19,919	0.575	0.0440	22.71	....	9.15	...	0.968	1.92	7.26
Ohio	...	...	...	...	80.5	18.2	...	1.3	1,143	1,034	22,966	20,775	0.650	0.0498	20.09	....	10.70	...	1.169	2.16	8.47
Pennsylvania	...	...	...	...	67.6	31.3	...	1.1	1,247	1,131	22,809	20,687	0.714	0.0547	18.29	....	11.66	...	1.302	2.29	9.22
California	0.8	...	...	...	75.1	23.0	...	1.1	1,174	1,063	22,548	20,416	0.680	0.0521	19.21	....	10.99	...	1.219	2.19	8.69
Coal gas																					
Horizontal retort	2.1	3.8	0.4	8.7	28.2	2.8	50.5	3.5	613	550	18,575	16,666	0.431	0.0330	30.30	....	5.32	...	0.566	1.240	4.24
Horizontal retort	2.8	4.5	0.6	7.4	34.3	...	41.6	8.8	609	548	16,133	14,517	0.493	0.0377	26.49	....	5.35	...	0.591	1.206	4.32
Vertical retort	3.0	3.1	0.6	7.0	32.8	...	50.4	3.1	569	507	18,718	16,679	0.397	0.0304	32.90	....	4.91	...	0.490	1.222	3.91
By-product coke oven gas.	2.1	3.2	0.4	6.4	30.3	...	53.9	3.7	563	502	19,452	17,344	0.378	0.0289	34.55	....	4.85	...	0.468	1.213	3.87
Water gas																					
Carburetted	3.3	10.7	0.7	33.4	10.0	...	38.1	3.8	562	521	11,274	10,452	0.651	0.0498	20.06	....	4.73	...	0.789	0.822	3.78
Carburetted	4.7	10.8	1.1	25.9	14.5	...	33.2	9.8	569	526	10,848	9,964	0.685	0.0525	19.07	....	4.86	...	0.775	0.865	3.94
Uncarburetted	5.0	...	0.5	44.0	2.0	...	44.0	4.5	305	281	6,717	6,189	0.593	0.0454	22.02	....	2.26	...	0.510	0.480	1.83
Pacific Coast oil gas	6.3	4.6	0.4	12.6	26.1	...	45.6	4.4	555	501	14,240	12,855	0.509	0.0390	25.66	....	4.79	...	0.594	1.083	3.83
Producer gas																					
Anthracite coal	6.6	0.3	...	25.1	0.3	...	18.7	49.0	149	139	2,325	2,169	0.837	0.0641	15.60	....	1.115	...	0.326	0.199	1.371
Bituminous coal	2.5	0.4	0.3	27.0	2.5	...	12.0	55.3	158	149	2,383	2,247	0.866	0.0663	15.08	....	1.210	...	0.328	0.178	1.509
Blast furnace gas	14.5	...	...	22.8	...	...	5.1	57.6	90	87	1,168	1,129	1.006	0.0770	12.98	....	0.665	...	0.373	0.051	1.101

Notes: *Figure calculated on assumption that substance could exist as gas at 60° F. and 30 in. of mercury.

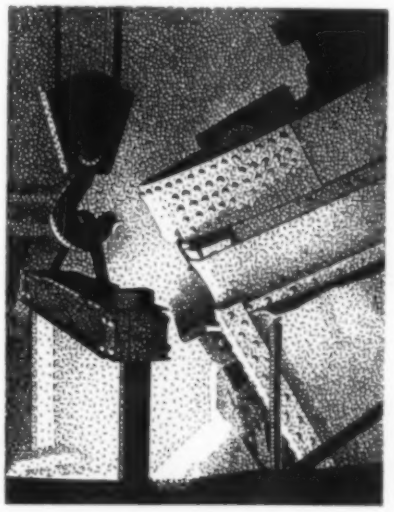
(*a*) Liquid
(*b*) Solid
(*c*) Contains 0.94% argon by volume, about 0.03% CO_2 and trace of hydrogen.
(*d*) Purified, dry air contains 20.99% oxygen and 79.01% nitrogen and other inert gases by volume (or 23.20% oxygen and 76.80% nitrogen by weight).

Improvement in Arc Furnaces and Accessories

By W. M. Farnsworth
Superintendent, Canton Steel Division
Republic Steel Corp.

METALLURGISTS in general have long recognized the ability of the electric furnace to produce cleaner, higher quality, more uniform alloy steels than could be obtained by any other process of steel making. A steady increase in electric furnace capacity has been the result — a trend which has turned sharply upward in recent months.

The newest electric arc furnaces, of which the four 50-ton units now installed or in the process of being installed in our Canton-Massillon division are typical, have individual, three-phase, 12,000-kva. transformers which combine several new ideas found desirable over a number of years of development and plant experience.



The tap changers are motor operated and offer a wide choice of voltages to the operator. The tap changing mechanism is mounted in a separate oil compartment attached directly to the transformer case. This prevents contamination of the oil in the main transformer by oil from the tap changing mechanism. A further advantage is that it requires only three high voltage bushings out of the transformer. All tap leads run from the terminal board inside the transformer case to the tap changer compartment inside the transformer and tap changer tank.

Electric furnace operators have found, too, that these larger furnaces require greater slag volumes, and a simple means of slag handling has been worked out in the new installations. Our new furnaces are designed and foundations so constructed that a car carrying the slag thimble can pass directly underneath the center line of the furnace. The car is motor operated and carries a 330-cu.ft. slag thimble (the same size as is used on a 100-ton openhearth). The oxidizing or melt-down slag is run off through the door directly opposite the tap hole, and after the heat is tapped and the ladle is removed, the slag thimble may be run forward to catch the drain from the furnaces.

Improved Reheating Furnaces

By P. M. Offill
Vice-President, The Amsler Morton Co.

TODAY, the insistent demand for increased production creates this problem: More production must be had in the same floor space. This is particularly true of the continuous heating furnace in steel mills, and another aid to production has been devised for them.

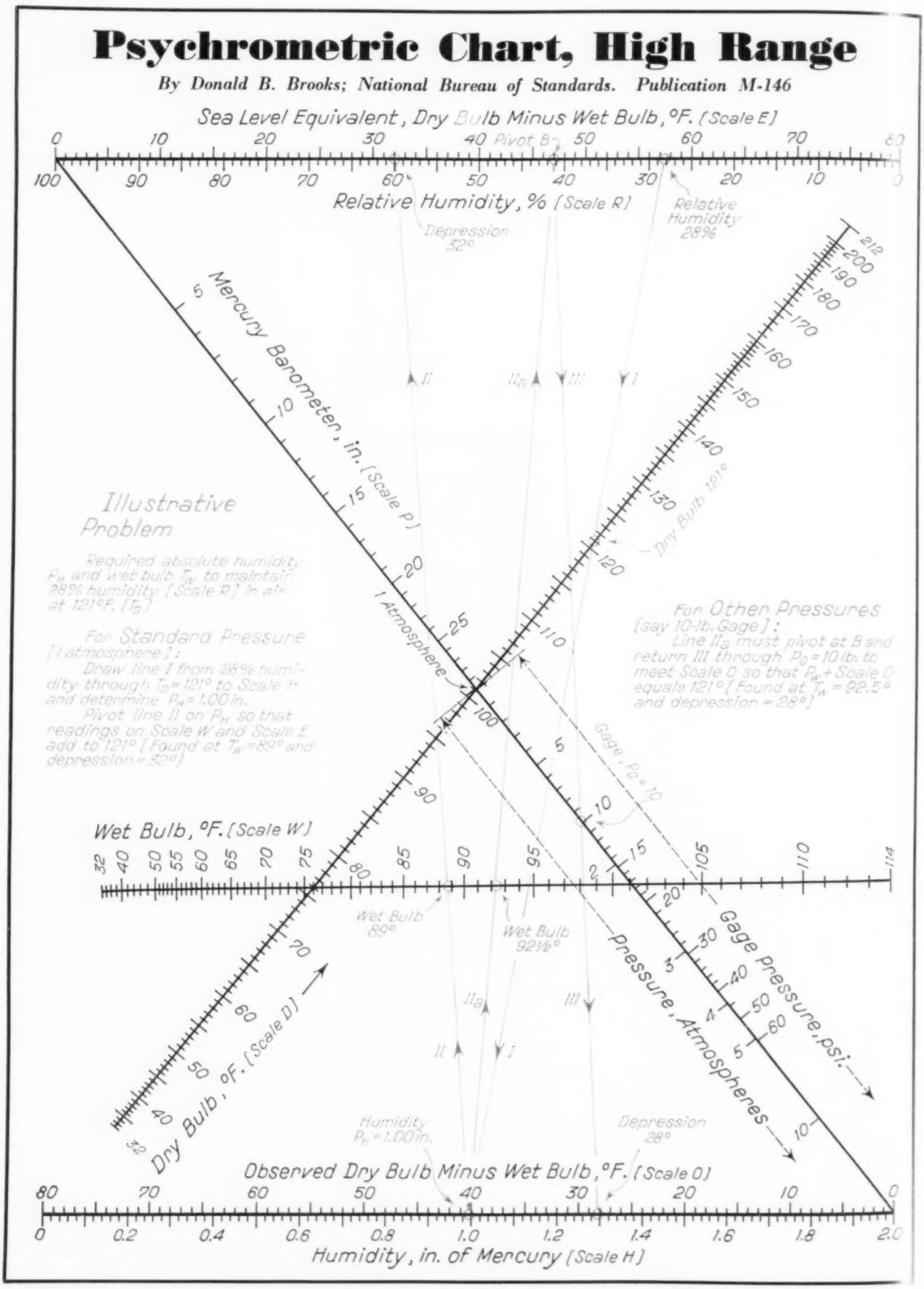
In the past, continuous heating furnaces have almost always been fired from the discharge end of the furnace. This, perhaps, is due to tradition; the early furnaces were quite small compared with the modern furnaces of today, and therefore were fairly easy to heat. As the furnaces became larger, problems of uniform and economical heating became more acute and improvements were made — but discharge-end firing was retained, probably on the basis that the steel could then most easily emerge at its highest temperature.

Some furnaces heat cold billets and others reheat hot steel from one train to prepare it for further rolling. It is common knowledge that a modern conventional continuous furnace will produce 25% more steel when the steel is charged at a temperature of 1500° F. We have taken advantage of this fact and install burners for proper firing at the *charging* end of continuous furnaces, with the result that our designs produce at a rate when heating cold steel that equals the output of modern conventional furnaces fired at the discharge end when reheating steel coming to them at about 1500° F.

Such an improved design obtains a uniform temperature throughout the length of the furnace which is about 100° F. higher than the average in the conventional furnace, but the maximum temperature is reduced by at least 100° F. "Washing" of the steel and the resultant slag are practically eliminated. This results in considerable improvement in the quality of heating as well as in reduced furnace maintenance.

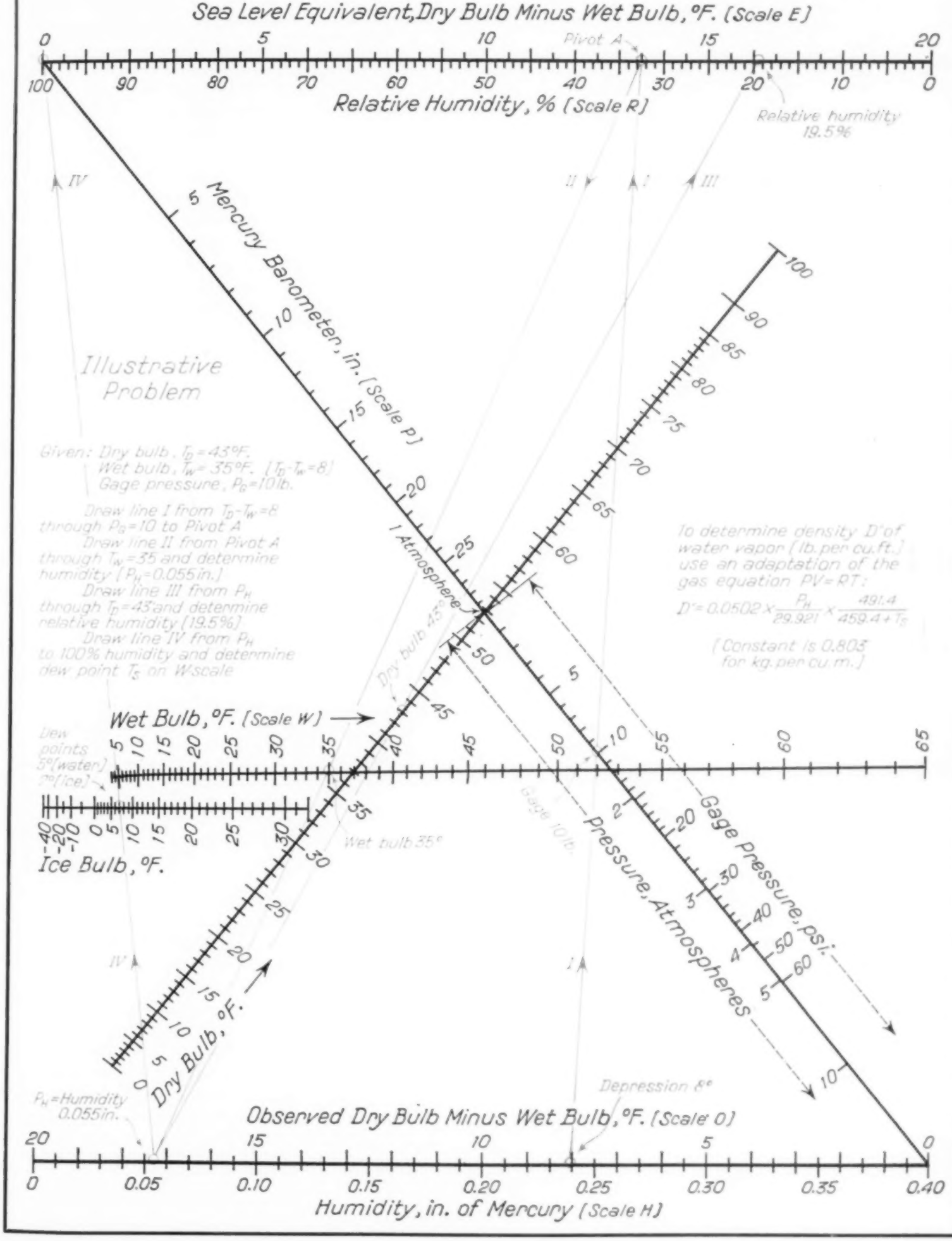
Psychrometric Chart, High Range

By Donald B. Brooks; National Bureau of Standards. Publication M-146


Sea Level Equivalent, Dry Bulb Minus Wet Bulb, °F. (Scale E)
0 10 20 30 40 Pivot B 50 60 70 80
100 90 80 70 60 50 40 30 20 10 0
Relative Humidity, % (Scale R)
Depression 32°
Relative Humidity 28%
Mercury Barometer, in. (Scale P)
5 10 15 20 25
1 Atmosphere
II IIa III I
Illustrative Problem
Required absolute humidity P_H and wet bulb T_W to maintain 28% humidity (Scale R) in air at 121°F. (T_D)
For Standard Pressure (1 atmosphere):
Draw line I from 28% humidity through T_D = 121° to Scale H and determine P_H = 1.00 in.
Pivot line II on P_H so that readings on Scale W and Scale E add to 121° (Found at T_W = 89° and depression = 32°)
For Other Pressures (say 10-lb. Gage):
Line IIa must pivot at B and return III through P_G = 10 lb. to meet Scale O so that P_W + Scale O equals 121° (Found at T_W = 92.5° and depression = 28°)
Dry Bulb 121°
Gage, P_G = 10
Wet Bulb, °F. (Scale W)
32 40 50 55 60 65 70 75 80 85 90 95 105 110 114
Wet Bulb 89°
Wet Bulb 92½°
Dry Bulb, °F. (Scale D)
32 40 50 60 70
Gage pressure, psi.
Pressure, Atmospheres
Humidity P_H = 1.00 in.
Depression 28°
Observed Dry Bulb Minus Wet Bulb, °F. (Scale O)
80 70 60 50 40 30 20 10 0
0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0
Humidity, in. of Mercury (Scale H)

Psychrometric Chart, Low Range

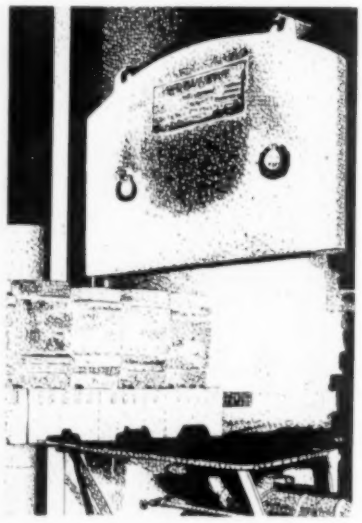
By Donald B. Brooks; National Bureau of Standards. Publication M-146


Sea Level Equivalent, Dry Bulb Minus Wet Bulb, °F. (Scale E)
0 5 10 Pivot A 15 20
100 90 80 70 60 50 40 30 20 10 0
Relative Humidity, % (Scale R)
Relative humidity 19.5%
IV II I III
Mercury Barometer, in. (Scale P)
Illustrative Problem
Given: Dry bulb, T_D = 43°F.
Wet bulb, T_W = 35°F. ($T_D - T_W$ = 8)
Gage pressure, P_G = 10 lb.
Draw line I from $T_D - T_W$ = 8 through P_G = 10 to Pivot A
Draw line II from Pivot A through T_W = 35 and determine humidity (P_H = 0.055 in.)
Draw line III from P_H through T_D = 43 and determine relative humidity (19.5%)
Draw line IV from P_H to 100% humidity and determine dew point T_S on W scale
1 Atmosphere
To determine density D' of water vapor (lb. per cu. ft.) use an adaptation of the gas equation PV = RT:
$D' = 0.0502 \times \frac{P_H}{29.921} \times \frac{491.4}{459.4 + T_S}$
(Constant is 0.803 for kg. per cu. m.)
Wet Bulb, °F. (Scale W)
Dew points 5° (water) 5° (ice)
Ice Bulb, °F.
Dry Bulb, °F.
Gage Pressure, psi.
Pressure, Atmospheres
P_H = Humidity 0.055 in.
Depression 8°
Observed Dry Bulb Minus Wet Bulb, °F. (Scale O)
20 15 10 5 0
0 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40
Humidity, in. of Mercury (Scale H)

Gas-Fired Furnaces

By Harry W. Smith, Jr.
Director of Industrial Publicity, American Gas Association

1940 HAS SEEN three relatively new techniques in gas utilization really take hold in the metal industries: *(a)* Continuous bright annealing of wire in *open* flames without furnace or atmosphere tube, *(b)* the application of gas radiants to the baking and drying of metal finishes by infra-red radiation, and *(c)* the successful adaptation of "submerged" or under-water combustion to the heating of pickling tanks and plating baths. In early 1939 all three were interesting possibilities — today all three are proven practicalities.



Open-flame wire annealing has permitted higher speeds and lower fuel costs, adapted the process to "straight-through" production lines and intermittent operation of strand-annealing lines without the necessity of waiting for heating-up periods. The anneal can also be controlled automatically by a device which actually "feels" the wire as it races on towards the final reel, and accordingly controls the chemical composition and temperature of the gases burning along the particular path followed by the wire as it pierces the long row of open flames. At least 30 such installations already exist, and are giving satisfactory service.

Gas radiants for baking synthetic finishes have capitalized the advantages of radiant heat in special types of work found by experiments with infra-red lamps (electric). Few believe that infra-red ray baking will supplant recirculated or convected hot air in the big finish-baking market, but for special jobs radiant heat is faster. In very few cases can convected heat be entirely foregone, for it is very useful for flushing evaporated volatiles out of the work chamber and for carrying heat into the shadows. Gas radiants offer a propitious combination of effective radiant heat for the sake of speed, and controlled convected heat for better results and versatility. At least a dozen applications of gas radiant burners to curing finishes on both ferrous and non-ferrous parts have been made recently.

Submerged combustion (where the flame actually burns under water) has succeeded in the job of heating pickling tanks because the agitation provided when the products of combustion bubble up through the bath is a highly desirable concomitant. The heating is also extremely efficient because of the total elimination of separations between flame and liquid. Further, the flue gases are reduced almost to the bath temperature before leaving it. By submerged combustion, a bath may not be heated beyond a certain theoretical temperature (around 165° F.), but in many operations such a limit is desirable.

Over and above these definitely new applications, several older heating methods have been more widely accepted. The gas-fired "Char-mo" furnace with its integral atmosphere generator, charcoal charged, has simplified heat treatment of the "touchy" molybdenum steels without decarburization or production of soft skin; the number of units installed has therefore pyramided. The Lithium Corp. has come out with an unusual gas-fired furnace for heating ferrous metals without decarburization or scaling by drawing some vaporous form of lithium into the work chamber from a special capsule. Also in the atmosphere field, the Industrial Research Committee of the American Gas Association has just issued its Bulletin No. 11, a report upon its three-year findings on furnace atmospheres made by the partial combustion of gas, either that used for heating or a separate supply. [NOTE: Mr. CONNER's article on the opposite page gives some of the conclusions.]

Gas-fired radiant tube applications are also increasing in number and the radiant tubes themselves are getting longer and longer. Thus the average size of such installations is growing. Austempering installations, all of them gas-fired and veritable models of automatic control, are slowly growing in number.

Finally, and most important, is the decided trend towards mechanization of industrial gas-fired heating equipment. Batch operations are becoming rarer each day. The speed of production demanded in connection with preparedness orders calls for gas furnaces which can fit into continuous automatic production lines and keep pace with all other equipment in the plant.

Carburizing Furnaces

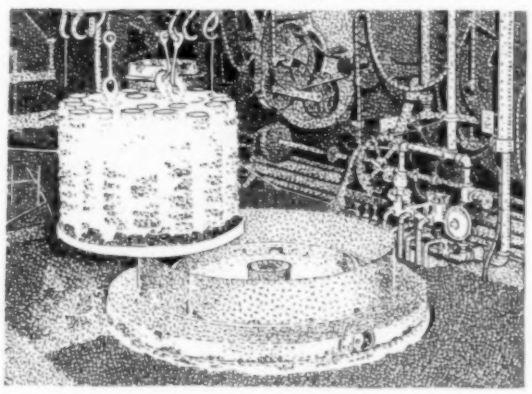
By J. A. Dow
Engineer, Holcroft & Co.

INDUSTRY has continued its rapid change from box carburizing to gas carburizing during the past year, not alone in the replacement of existing furnaces but especially in the installation of new equipment.

Lower operating costs, better control of the type of case produced, less floor space required and greatly improved working conditions with gas carburizing have all been factors influencing this change.

In batch furnaces, the rotating retort type and the pit type continue to be the most popular. Where densely packed loads have to be handled, the vertical pit type furnace, equipped with a fan providing forced circulation of the carburizing gas through the load, has definitely proven itself an accurate and economical heat treating machine.

In the continuous furnace field, the most noteworthy development of the past year has been the expanding use of radiant tube heating, which eliminates the need for the alloy muffle. These radiant tubes can be replaced



while the furnace is hot; a tube failure, then, usually causes no interruption to production schedules — it is merely blanked off until it can be replaced. This type of construction also permits the use of circulating fans in the furnace chamber. A very high degree of uniformity in the case is being obtained in spite of a very dense loading of small parts in a furnace equipped with three generous sized circulating fans. Modern furnaces both of the muffle and muffle-less type were described at some length and illustrated in METAL PROGRESS last month by Messrs. WYZALEK and FOLKNER.

Progress in the direction of cleaner gas carburized work has also been made in the past year. More accurate control of the carburizing atmosphere has not only made for cleaner work but a more uniform product from day to day and week to week.

Preparation of Controlled Atmospheres by Partial Combustion of Gaseous Fuels

By R. M. Conner
Director, Testing Laboratories, American Gas Association

IN GENERAL, heating operations are relatively simple when oxidizing atmospheres can be used; combustion may then be maintained easily and efficiently with a slight excess of air, and the effect of the flue gases on various heated materials is rather well established. In many other cases, however, it is desirable to surround the material being heated with an atmosphere of controlled composition which is neutral in its chemical effect on the work. Methods for doing this have been developed industrially by the method of trial and error, and the published data are incomplete and seemingly contradictory. To clarify this situation the Testing Laboratories of the American Gas Association started three years ago to investigate the problems of combustion of natural gas and typical manufactured gases with limited air supply, and some of the results to date have been published in its Bulletin No. 11.

Among other things it has been found that a general statement that a flue gas of given composition will carburize, decarburize, oxidize or deoxidize a metal cannot be made. A gas of given composition may carburize one steel and decarburize another, or it may carburize a steel at one temperature and decarburize the same steel at a different temperature. The same holds true for oxidation and deoxidation. When flue gas atmospheres remain in contact with metals at high temperatures there is a tendency for them to react chemically until an equilibrium is established between the two. These conditions of equilibrium change with original gas composition, temperature, original carbon content in the steel, and alloying elements in the steel. In general, the longer a gas remains in contact

(Continued on page 596)

Furnaces for Tool Hardening

By A. H. d'Arcambal
Past-President
Consulting Metallurgist, Pratt & Whitney

TOOL HARDENING FURNACES, I would say, are about in the same state of design and construction as exhibited at the Exposition in Chicago last fall. The majority of tool manufacturers in the Eastern section of the country continue to use electric globar furnaces with atmospheric control for hardening high speed steel. Many of these furnaces now are equipped with the new type terminals, doing away with water cooling and resulting in a nice saving in current consumption. The new family of metallic resistors, capable of operating at the high temperatures necessary, have not yet been used to any considerable extent — at least in the regions where I am most familiar.

There are more and more salt bath furnaces with the electrode type immersion heating elements being employed where tools are produced on a production basis from one of the many types of molybdenum high speed steels now on the market. It has been our experience that this is the best equipment for hardening of these molybdenum tools although we use but a little of these analyses in comparison with the tonnage of "standard" high speed.

In regard to the hardening of carbon steel tools, practically all tool manufacturers are using electrically heated lead baths for hardening such tools as taps, reamers and some types of dies, and employing either the electric or gas fired box type furnace for hardening carbon steel cutters, tools made of so-called air hardening die steel and of high carbon, high chromium steel.

In this connection many interesting developments have been made in the field of atmosphere control. Several different types of furnaces are being used wherein the atmosphere is 100% prepared, the composition controllable, and quenching without exposure to the outside air.

For tempering carbon, alloy and high speed steel tools, the air drawing furnaces of the latest design are giving excellent results. Some manufacturers still prefer oil baths for drawing the carbon steel tools, and salt or lead baths for tempering tools made of high speed steel. However, I feel certain that the large majority of carbon, alloy and high speed tools are tempered in air drawing furnaces, and with extremely satisfactory results.

Salt Baths and Furnaces Therefor

By William Adam, Jr.
Vice-President, Ajax Electric Co.

COMPARATIVELY LITTLE appears in current metallurgical literature about salt baths and salt bath furnaces, but that does not reflect the true situation in this branch of heat treatment. Many of the things that are being done do not readily translate into newsy editorial copy, yet if counted would compare most favorably to the progress in other fields — say, of controlled atmosphere.

Consider the mediums: Gas atmospheres for the most part consist of chemical compounds well known in elementary chemistry, and it is easy to erect a plausible hypothesis about how they react with each other and the hot metal (but not so easy, one may venture to remark, to make them act that way in an operating furnace). On the other hand, the chemistry of molten salt mixtures is a closed book to most metallurgists, and it may as well be admitted that better salts for specific purposes are largely discovered by trial and error and their composition held private as long as possible. (Who, for instance, would assume that molten barium chloride — a very stable salt at high temperatures — would decarburize high speed steel, or predict HULTGREN's discovery in 1930 that the addition of a siliceous oxide to the bath would prevent any decarburization?) Despite this somewhat fumbling method of approach, salt baths are now available for all parts of the range from 300 to 2400° F., and of a nature that adds carbon, nitrogen or both to steel, or which

are inert and protective to steel, aluminum, precious metals, or copper alloys.

Outstanding advantages of salt baths for heating mediums are the temperature uniformity within the bath, its accurate control, the rapid heat transfer to the work, and the controlled surface effect. Among the earliest baths was cyanide for casehardening; this application is still widely used and many new installations using modern furnace settings are being made in competition with modern gas carburizing equipment. Typical is the one at Norge refrigerator plant described in METAL PROGRESS in Sepember 1939. Internal heat, generated by passage of current between submerged electrodes, is not only very efficient from a cost standpoint, but saves the pot as well. Induced circulation, produced by electromagnetic forces at and around the electrodes, keeps the temperature rigorously uniform throughout the melt.

High temperature heating requires stable salts at high temperature. Given this, our firm has been able to introduce salt baths for heating steel for forging. Specific applications are for forging golf club heads and automobile steering knuckles. One manufacturer of forging machinery uses a salt bath for reheating billets for all test runs on new machines. A rather timely application is the recent introduction of our salt bath furnace in several ordnance plants for selectively heating nothing but the ends of artillery shell forgings prior to the nosing operation.

As to the hardening of high speed steel, 15 of our installations made during the last two years have convinced us, as well as these customers, that the salt bath method of hardening will produce tools with no decarburization, and of more uniform hardness than they have been able to do with atmosphere equipment. Moreover, results are equally effective regardless of the type of steel used, 18-4-1, 12-4-2, molybdenum-tungsten, the high vanadium types, or the cobalt high speeds.

In the more moderate range of temperature, a most unique development is the brand new idea of using a salt bath for dip brazing various ferrous and non-ferrous assemblies. Several commercial installations have been made for brazing such work as copper-finned heat exchange units, oil filters of steel, and other automotive parts. The method was briefly described by the Editor in "Critical Points" in the May issue.

Large mechanized salt bath furnaces are especially noteworthy, and are only possible because of the extended pot life insured by internal heating. The hazards of premature pot failure, excessive fuming, and radiated heat were great handicaps to fuel-fired salt bath furnaces of the continuous type. Today there are almost a score of conveyorized furnaces in the automotive industry, some with baths up to 18 ft. in length, used on heat treating operations such as hardening timing chain links, selectively cyaniding the ends of valve pusher rods, carburizing boiler stay-bolts, and hardening automobile generator and starter shafts.

Combustion Control

By E. G. deCoriolis
Research Director, Surface Combustion Corp.

UNTIL VERY RECENTLY the designation "combustion control" referred almost exclusively to the problem of the economical utilization of a fuel — in other words, to problems concerned with the oxidation of hydrogen, carbon and hydrocarbons so that a maximum heat would be liberated. This problem has been solved by the use of the carbon dioxide analyzer and its attendant fuel-air proportioning equipment, as evidenced by its increasing use in large power plants.

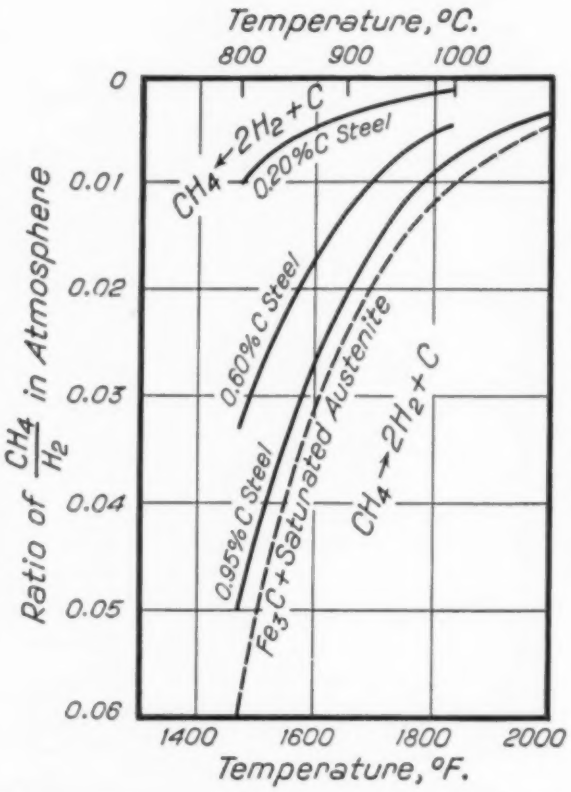
However, combustion control is by no means so limited in its interpretation. It may quite logically be applied to endothermic reactions as well as exothermic, partial oxidation as well as complete combustion, and for the preparation of complex gases as well as for the liberation of heat.

As a matter of fact combustion control, or more truly *control of combustion*, is as much needed in the preparation of special gases used both for protective, inert and active furnace atmospheres as for the pure liberation of heat.

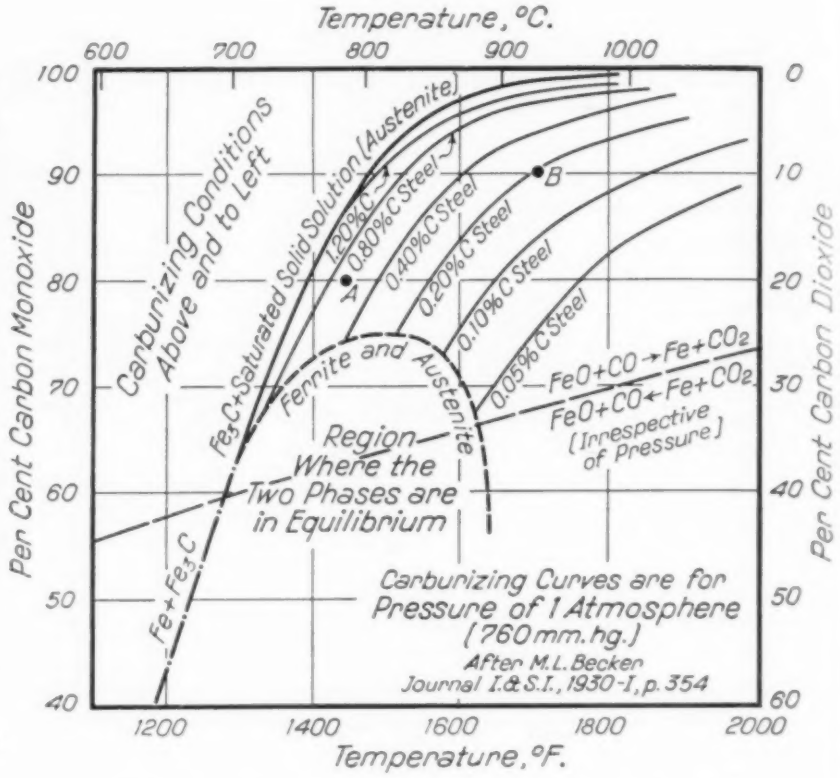
In the class of those processes where the product desired is a protective atmosphere (as for the annealing of steel sheets) the whole process depends on the control of the totally exothermic reaction to maintain certain ratios of the constituents of the final gas. In this case the heat liberated is too small to be of any use in the actual heating of the steel sheets, which fact, together with other considerations, necessitates a separate chamber for this combustion process.

Equilibria for Gas-Steel Reactions

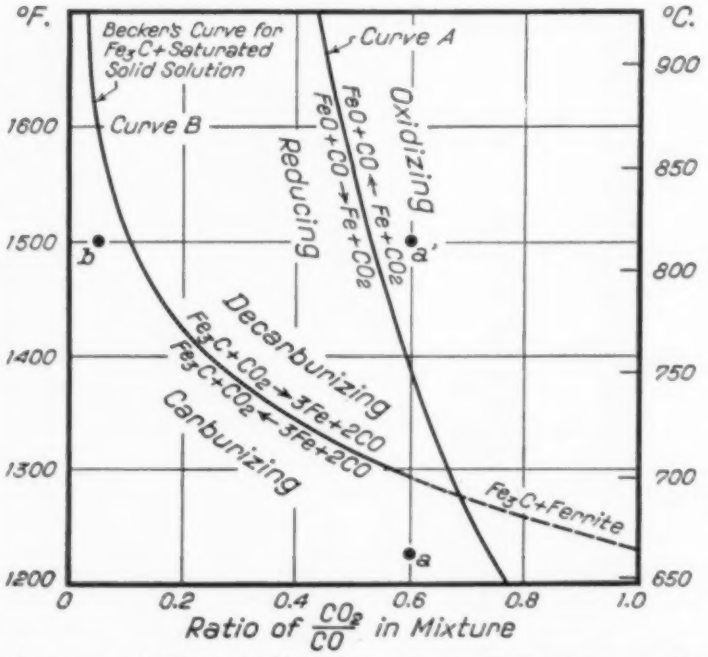
Relation Between Gas Composition, Temperature, and Carbon Content in Steel



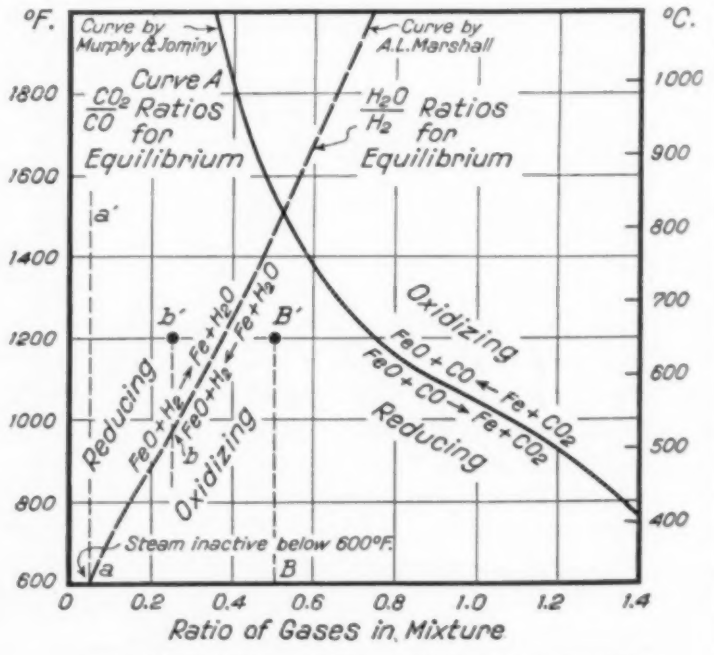
Above Curves, Adapted by Stansel From Sykes' Work, Indicate That Almost Pure H_2 Decarburizes Hot Steel (Conditions Above and Left of Corresponding Curves). Methane breaks down almost completely into carbon and hydrogen, carburizing steel (and depositing excess soot) at conditions below curves



Carburizing Reactions Depend on Carbon in Steel. Thus: 80% CO, 20% CO_2 at 1450° F., (point *A*) will carburize 0.40% C steel and lower, but decarburize 0.80% C steel and higher. However 90% CO, 10% CO_2 at 1700° F., (point *B*) is relatively inert to 0.20% C steels, will carburize lower carbon and decarburize higher carbon steels. Partial pressures, i.e., $CO + CO_2 < 100\%$, raise curves and shift to left



Action of Carbon Oxides Depends on Temperature. For instance, a dried atmosphere containing 6% CO_2 and 10% CO or ratio 0.6 (easily secured by partial combustion of fuel gas) would tend both to reduce and carburize at a 1225° F. anneal (Point *a*), but would both decarburize and oxidize at 1500° F. (Point *a'*). For "bright hardening" the CO_2 must be reduced well below Curve *B* (for instance, 1/10 the CO, as Point *b*, at 1500° F.). The above statements neglect the fact that the pressure of CO + CO_2 is less than 1 atmosphere



Oxidizing Action of Steam May Be Counteracted by 20 Times As Much Hydrogen (Line *a-a'*). Larger proportions of steam may scale the metal during cooling (line *b'-b*). Oxidizing — and decarburizing — propensities of moist gas may likewise be counteracted by carrying excess CO in the mixed carbon oxides present in the furnace atmosphere (for instance, $CO_2 : CO = 0.5$, or line *B-B'*, on the reducing side of curve *A*)

Speaking broadly, the above are all chemical reactions but they also all fall into the category of partial oxidation which we know by the term "combustion". With that consideration in mind, probably the term "control of combustion" would be the more descriptive term and one that expresses the problems involved more clearly.

In the research and experimental work attendant to the development of these special atmospheres, mentioned above, whose final compositions have become fairly well defined, evidence of intermediate products of very interesting and useful characteristics have been encountered.

These intermediate products will eventually be made available only through the *control of combustion*. However, until new types of gas analyzing equipment can be made available to determine, quickly and accurately, the composition of the individual components of these intermediate products, little can be done in the way of combustion control.

This is especially true in developments now in progress where constituents are introduced into the combustion process other than, and in addition to, the usual fuel and oxidizing agent. The reactions encountered in this work are both endothermic and exothermic and require an accurate balance to maintain the desired end product.

Not only do we encounter those curious and as yet little known reactions and intermediate combustion products in the generation of special atmospheres but we also find, in the few cases where we can exercise a slight control over combustion, that the different intermediate combustion products exert an enormous influence in the overall process of combustion. In certain applications we have had to revise our previous conceptions completely about the phenomena of combustion, especially that relating to combustion in confined spaces.

To date various manufacturers of this type of equipment for the simpler forms of special atmospheres have utilized more or less conventional systems for control of combustion which, regardless of their mechanical principles of operation, all fall into one or two general classes, namely, the volumetric or gravitational proportioning of the fuel to be utilized and of its oxidizing agent.

In some few cases continuous indicators and recorders (such as those described by Messrs. SLOWTER and GONSER on page 555 of this issue) have been utilized for showing the quantity of one of the constituents of these complex combustion products, and by the inference that there has been no change in the quality or composition of the fuel and its oxidizing agent, use this indication to control, by hand, the operation of the combustion process.

It is quite evident that until equipment can be devised for showing directly the quantity of the influential element in the combustion gases, no attempt can be made to procure a truly automatic control of combustion.

Problem of Uniformity in Furnace Output

By Stewart N. Clarkson
Executive Vice-President
Industrial Furnace Manufacturers Association, Inc.

MONTHS BEFORE MUNICH the Industrial Furnace Manufacturers Association started a campaign to help the Ordnance Department to obtain greater uniformity of metals and metal products used for war purposes. While the automotive and some other industries have achieved close to the maximum possible uniformity in their heating and cooling processes by a long campaign of metallurgical education, there are too many industries and individual shops which must carry a part of the rearmament program where comparable results are not being achieved.

The industrial furnace manufacturers individually, and collectively through their Association, have done what they could to emphasize the need of uniform metal products and the means of obtaining such uniformity through uniform heating and cooling in existing furnaces. Their services have been made available to the government, and are also available to industry generally for the purpose of outlining means by which uniform products may be obtained with existing equipment. While it is nearly always true that uniform products may be obtained with existing furnace equipment, this usually reduces the production of heated parts per furnace load.

An example of this was found in connection with the furnaces necessary to produce current orders for shell forgings, particularly in the 75-mm. to 155-mm. sizes. Rotary hearth forging furnaces were being considered of such small physical dimensions that the desired output could only be secured by operating at exces-

(Continued on page 604)

Preparation of Controlled Atmospheres

(Continued from page 591)

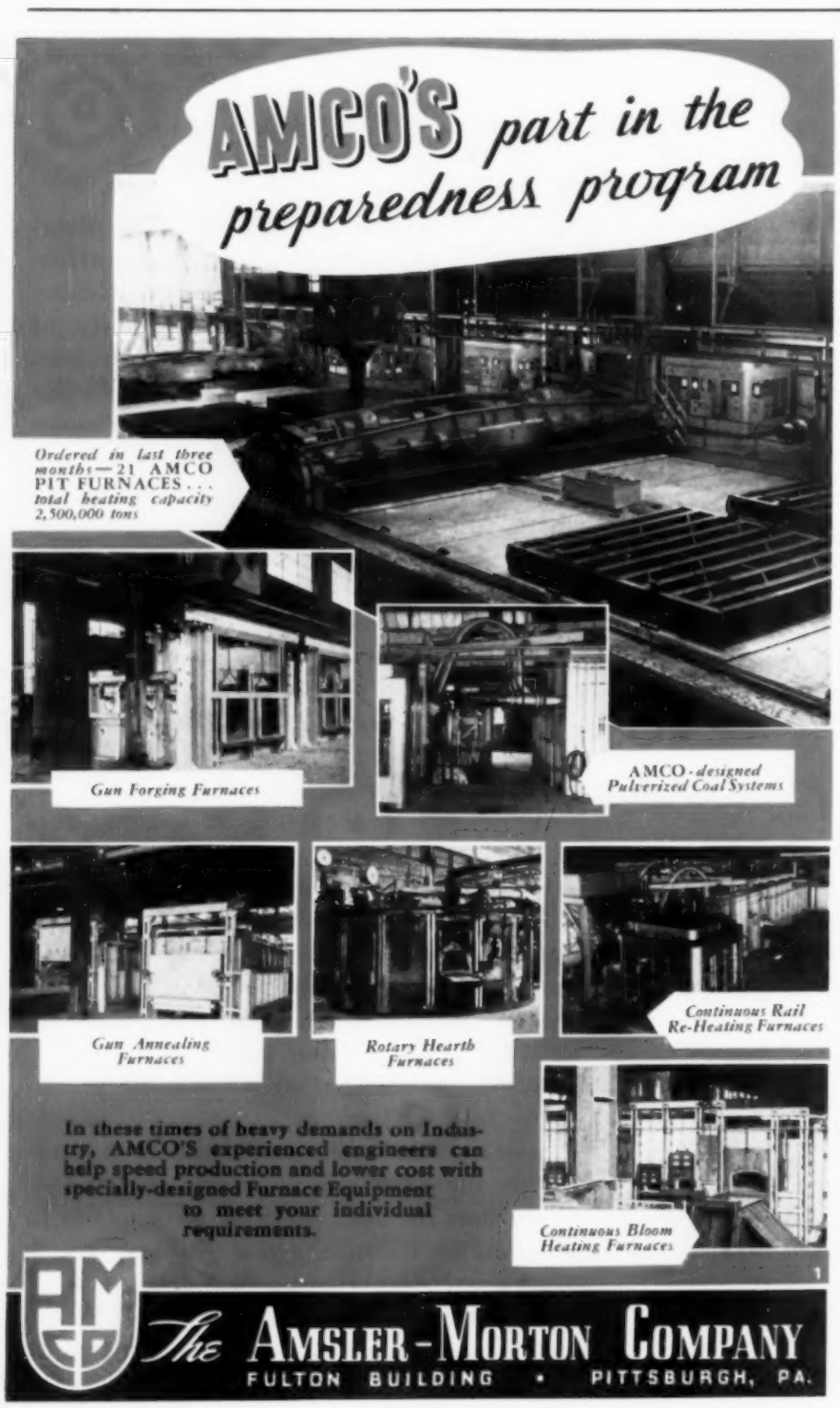
with metal at high temperatures, the closer the atmosphere composition must be to that which will be in equilibrium with the composition desired at the metal surface.

A comparison of these equilibrium conditions with the composition of flue gases obtained in our studies shows that in every case the untreated gases obtained by partial combustion of natural and manufactured gases would be oxidizing and decarburizing in nature toward plain carbon steels. This is due to the relatively high amounts of CO_2 and H_2O, with respect to CO and H_2, in the flue products even at low aerations. Therefore, if an atmosphere definitely non-oxidizing to steel is required, it is necessary to remove part or all of the water vapor and carbon dioxide by cooling and by chemical absorption.

Untreated atmospheres produced by burning industrial gases with approximately 95% of the air required for complete combustion (95% aeration) have been found very satisfactory for bright annealing copper and clean annealing brass. Such atmospheres contain a minimum concentration of oxygen and small concentrations of the reducing constituents, carbon monoxide and hydrogen. Limitation of these atmospheres with respect to brass arises from a tendency of zinc to boil out of the surface of brass at annealing temperatures and not from inherent limitations of the atmospheres. There are definite indications, however, that suitability of these atmospheres arises in part from minimum oxygen concentrations in the flue products occurring with this degree of aeration.

Although scaling at the surface of metals may be decreased by using atmospheres produced by combustion at low aerations, other reactions may occur at the same time which are as objectionable as scaling. For example, such atmospheres may decarburize the metal surface because of the high hydrogen content of the gases. Moreover, scale produced in atmospheres made by partial combustion of gas has been reported as being of an adhering type, which may be less desirable than a heavier but free-scaling type which falls off in subsequent processing.

Composition of flue gas atmospheres undoubtedly will change somewhat as their temperatures are changed but this composition change probably will be small; indeed composition should remain constant during any temperature changes below 1600° F.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Even if flue gas atmospheres, in contact with iron oxides or other catalytic substances, changed composition at high temperatures in accordance with the so-called water-gas reaction, maximum change in concentration of any one constituent for a decrease in temperature from 2300 to 1900° F. would be approximately 1% of the total dry flue products. If, therefore, the analysis of an atmosphere is known for one operating temperature, it can be assumed without great error that the analysis will also apply unchanged at another heat treating temperature.

Premixing type burners are generally to be preferred to diffusion or nozzle-mixing types for producing flue gas atmospheres of uniform composition. Higher turn-down ratios are possible without flash-backs to the premixing chamber; more uniform composition of flue products also results when a number of small ports are used instead of one larger burner port. Ceramic materials placed around or close to the burner ports, which become incandescent, are very helpful in keeping the flame burning smoothly at low aerations.

It also should be noted that in general atmospheric type burners are not adaptable to combustion of gas at very low aerations because of the low burner head pressures available. There is a propensity for flames to flash back to the mixing chamber, to smother in the combustion chamber, or for explosive pockets of unburned gas to be formed in the combustion chamber.

If it is desired to produce large concentrations of carbon monoxide and hydrogen in the flue products by combustion at very low aerations, several expedients may be used to lower the minimum amount of air which will support combustion. Radiation from the combustion tube was found to have an important effect. Well-insulated ceramic combustion tubes are preferable because shorter and more stable flames are formed, less unburned hydrocarbons remain in the flue products, and higher inputs can be employed. The minimum aeration which would support combustion of natural gas in the ceramic and water-cooled experimental furnaces was 67 and 77%, respectively, of the total air required for theoretically complete combustion. Similarly, manufactured gases could not be burned below 53 and 58% aeration in the ceramic and water-cooled combustion tubes, respectively.

It is quite possible that improved designs of burners would enable still lower aeration mixtures of both gases to be burned. It is also likely that preheating the air supplied for combustion would lower the aeration limit at which fuel gas can be burned.

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H-T SUPEREX BLOCKS. For many years the most widely used block insulation for temperatures to 1900° F. Combines high heat resistance and low thermal conductivity. Furnished 3" to 12" wide; 18" and 36" long; from 1" to 4" thick.

L-W SUPEREX BLOCKS AND PIPE INSULATION. New-type Superex Block and Pipe Insulation for temperatures to 1500° F. Light in weight, high in insulating efficiency, unusually resistant to compression and breaking. Pipe Insulation in all sizes. Blocks same sizes as H-T Superex.

SIL-O-CEL NATURAL BRICK. A highly efficient back-up insulation for temperatures to 1600° F. Standard firebrick sizes and shapes.

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JM-20 BRICK. New-type insulating-refractory brick for temperatures up to 2000° F. Unusually light in weight (1.9 lbs. per standard 9" equivalent). Standard firebrick sizes and shapes.

LOW CONDUCTIVITY	This, of course, is the first thing you look for in insulation. Because Johns-Manville Insulations provide lowest conductivity consistent with strength and other essentials, they assure initial high fuel savings that continue throughout years of service.	✓
TEMPERATURE RESISTANCE	To maintain its original effectiveness, the insulation you use must remain unaffected by the temperatures to which it is subjected. From the complete line of J-M Insulations, you can select the right material for any temperature from 400° F. below to 2500° F. above.	✓
CRUSHING STRENGTH	In locations where it is subjected to compressive loads, the insulation must be able to maintain its strength and true form, even while heated to service temperatures. For such services, the J-M line offers insulating materials with unusually high load-bearing capacities.	✓
BREAKING STRENGTH	Resistance to breaking is important in guarding against damage during transportation and installation. Certain services also demand more than ordinary toughness in insulations. Many J-M materials have unusually high resistance to breaking, as measured by transverse strength.	✓
FULL THICKNESS	For maximum insulating protection, the insulation you use must not sag or compress during application, or deteriorate in service. J-M Block and Pipe Insulations are designed to avoid such dangers . . . and they can be applied without risk of voids or thin spots.	✓
MOISTURE RESISTANCE	This feature is particularly important in refrigeration service, since moisture infiltration causes most low-temperature insulation failures. J-M Refrigeration Insulations offer unusual moisture resistance, and, because of their basically mineral composition, are rotproof and verminproof as well.	✓
STABILITY IN SERVICE	If maximum fuel or refrigeration savings are to continue indefinitely, the insulation you use must not only possess the above characteristics at the start, it must retain them throughout the life of the equipment on which it is used. The column at the left gives some brief facts on a few of the many J-M Insulating Materials.	

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CYCLONE WAS THE BIG NEWS OF THE '35 SHOW...

IT'S BIGGER NEWS TODAY!

1935

CHICAGO, 1935—A new kind of furnace made headline news at the 1935 Metal Show. It was the Lindberg Cyclone Tempering Furnace—so genuinely a product of experience that heat treaters acclaimed it immediately with orders and installations in every part of the country.

Pioneering an entirely new kind of heating—the Cyclone had been subjected to 12 months of probation in the Lindberg Steel Treating plant before announcement in February of 1935. Here, for the first time, was positive-pressure, two-mile-a-minute circulation, combined with armor plate construction, so that this Cyclone provided laboratory heating accuracy plus battleship ruggedness to stand up on the production line day in and day out—24 hours a day—without the slightest tendency toward faltering.

The news of the Cyclone traveled fast, and by Metal Show time in 1936 the Cyclone had skyrocketed to first place in the tempering furnace field. 1937, 1938, 1939 saw the Cyclone making bigger headlines, not only in this country, but in China, Japan, Australia, South Africa, Russia, England, France, and South America, as well.

1940

CLEVELAND, 1940—and *today* the Cyclone is bigger news than ever, because industry is in the midst of a vast Defense Program and Cyclones are in action in practically every major aircraft, automotive, farm implement, and ammunition plant in the nation. And every day more Cyclones go to work—in fact the demand for Cyclones is so great that the seventh plant expansion of the Lindberg Factory has just been completed—with floor space increased fifty per cent.

So, if you're not using the Cyclone in your plant, visit the Lindberg Booth at the Metal Show and see why this furnace has so consistently been in the headlines. Look it over from stem to stern. Just a glance at the massive top casting will show you why this brute of a furnace will take all the abuse you can possibly give it.

See how heat is generated in a separate chamber so that radiation from heating source to work is impossible—see the powerful Cyclone blower fan that delivers heat to the work at two miles a minute. See why Cyclone Tempering is still in the headlines after five years.

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Uniformity of Furnace Output

(Continued from page 595)

sive temperatures. This practice can only result in non-uniformly heated billets and excessive furnace maintenance.

In accordance with the industry's plan of cooperation with the Ordnance Department, the special committee which had been appointed to meet such contingencies reviewed the situation and suggested an amendment to the government's shell forging specification, in the form of a recommended practice containing definite size and temperature limitations. These recommendations were referred to the arsenals and large suppliers of shell forgings, and upon their endorsement were adopted by the War Department as of July 2, 1940, and issued as Amendment No. 2 to Shell Forging Specification No. 57-104-2B, reading as follows:

H-3. For the information of the manufacturer, the following recommendations on temperature control and furnace loading are considered good practice in connection with the forging of artillery shells:

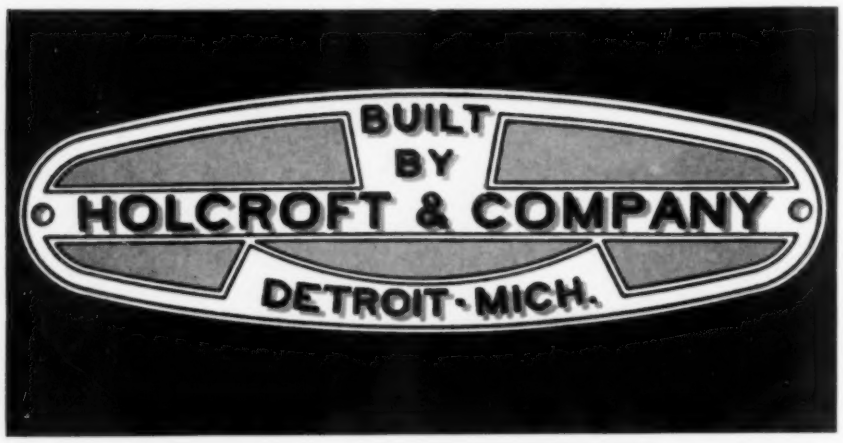
H-3a. The operating temperature of forging furnaces should be restricted to a maximum of 2300° F. to avoid overheating the surface of billets to the point where the steel drips or flows.

H-3b. The loading of forging furnaces should be limited to not more than 60 lb. of steel heated per hr. per sq.ft. of hearth area available for loading, to prevent slag formation in the furnace.

H-3c. Each billet should be exposed in the furnace for individual heating, to avoid non-uniformity in the billet, such as hot surface with relatively cold centers, and to permit uniform and continuous press operation by providing uniformly heated billets.

The industrial furnace business is of such an individual character that it is difficult, if not impossible, to standardize on most features in connection with the larger furnaces. However, the manufacturers felt that it was their duty in this emergency to reach an agreement on this important matter. Therefore, for the first time in its history, a standardized basis of rating — a loading yardstick — was adopted for shell forging furnaces.

Most users of furnaces have one or more suppliers upon whom they depend for information and advice in connection with their furnace problems, but if there is anyone not so situated such information can nevertheless be obtained through the officers of the Industrial Furnace Manufacturers Association.



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